Investigation of Spontaneous Abortion Among Video Display Terminal Users

FINAL REPORT
March 1991

Teresa M. Schnorr, Ph.D.[1]
Barbara A. Grajewski, Ph.D.[1]
Richard W. Hornung, Dr. P.H.[1]
Michael J. Thun, M.D.[2]
Grace M. Egeland, Ph.D.[1]
William E. Murray, M.S.[1]
David L. Conover, Ph.D.[1]
William E. Halperin, M.D.[1]

[1] National Institute for Occupational Safety and Health
4676 Columbia Parkway, Cincinnati, Ohio 45226

[2] American Cancer Society
1599 Clifton Road, Atlanta, Georgia 30329

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. PB91-189209

4. Title and Subtitle
Investigation of Spontaneous Abortion among Video Display Terminal Users

5. Report Date
1991/03/00

6.

7. Author(s) Schnorr, T. M., Grajewski, B. A., Hornung, R. W., Thun, M. J., Egeland, G. M., Murry, W. E., Conover, D. L., Halperin, W. E.

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
National Institute for Occupational Safety and Health
4676 Columbia Parkway
Cincinnati, Ohio 45226

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C)
(G)

12. Sponsoring Organization Name and Address
National Institute for Occupational Safety and Health
4676 Columbia Parkway
Cincinnati, Ohio 45226

13. Type of Report & Period Covered
Final Report

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

NIOSH conducted a study of 2,430 female telephone operators to determine if exposure to electromagnetic fields emitted by video display terminals (VDT's) were associated with increased risk of spontaneous abortion. Exposure levels were determined using company records of weekly hours of VDT use and measurements of electromagnetic fields at VDT workstations. Operators who used VDT's had higher abdominal exposure to very low frequency (VLF) (15 kHz) electromagnetic. Workstations without VDT's did not emit VLF energy. Abdominal exposure to extremely low frequency (ELF) (45 to 60Hz) was similar for operators who used VDT's and those who did not. The authors found no excess risk of spontaneous abortion for VDT use in the first trimester of pregnancy and no dose-response relationship resulting from weekly hours of VDT use. Significant associations were found for other risk factors e.g. cigarette smoking, thyroid disorder, alcohol consumption. The potential association of spontaneous abortion and physical or psychological stress could not be addressed in the study design. The authors conclude that VDT use and exposure to the accompanying electromagnetic fields were not associated with an increased risk of spontaneous abortion in this study.

17. Document Analysis a. Descriptors

NIOSH-Publication, NIOSH-Author, Reproductive-system-disorders, Workplace-studies, Office-workers, Computer-equipment, Radiation-exposure, Nonionizing-radiation, Radiation-hazards

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Available to the public	Unclassified	26
	20. Security Class (This Page)	22. Price
	Unclassified	

ABSTRACT

The relation between spontaneous abortion and video display terminal (VDT) use is of great public health concern. Previous studies have reported inconsistent findings. To determine if electromagnetic fields emitted by VDTs are associated with an increased risk of spontaneous abortion, a cohort of female telephone operators who used VDTs at work was compared to a cohort of operators who did not use VDTs. To obtain reliable estimates of exposure, we determined the weekly hours of VDT use from company records and measured electromagnetic fields at VDT workstations and, for purposes of comparison, at workstations without VDTs. Operators who used VDTs had higher abdominal exposure to very low frequency (15 kHz) electromagnetic fields (workstations without VDTs did not emit very low frequency energy). Abdominal exposure to extremely low frequency fields (45 to 60 Hz) was similar for both operators who used VDTs and those who did not. Out of 2,430 women interviewed, there were 882 eligible pregnancies.

We found no excess risk of spontaneous abortion for VDT use in the first trimester of pregnancy (odds ratio = 0.93, 95% CI=0.63-1.38) and no dose-response relation when we examined the weekly hours of VDT use (odds ratio for 1-25 hours/week = 1.04, 95% CI=0.61-1.79; odds ratio for > 25 hours/week = 1.00, 95% CI=0.61-1.64). This absence of risk was not altered when we accounted for multiple pregnancies per woman, conducted separate analyses of early abortion, late abortion and all fetal losses; or limited analyses to abortions for which a physician was consulted. Significant associations were found for other risk factors previously reported in the literature: spontaneous abortion prior to study period, heavy cigarette smoking, thyroid disorder and greater than 8 alcoholic drinks/month. The potential association of spontaneous abortion and physical or psychological stress could not be addressed in this study design.

We conclude that VDT use and exposure to the accompanying electromagnetic fields were not associated with an increased risk of spontaneous abortion in this study.

INTRODUCTION

Concern about the potential reproductive effects of video display terminal (VDT) use began in 1980 when a cluster of birth defects was reported among women who used VDTs at the Toronto Star newspaper.[1] Following this initial report, other clusters of adverse pregnancy outcomes, primarily spontaneous abortion, were reported.[2-5] Subsequently, several investigators conducted epidemiologic analyses of VDT use and pregnancy outcome.[6-16] Most of these studies showed no effect or equivocal results.[6-14] Two studies showed a significant increased risk of spontaneous abortion for women who reported using VDTs greater than 15 hours[15] and 20 hours[16] per week. Only a few of these studies were initially designed to evaluate potential reproductive effects of VDTs.[11-13] All of these studies utilized interview responses[11-16] or job title data[6-10,14,15] to estimate VDT use. None measured the electromagnetic fields produced by the VDTs.

Three hypotheses have been proposed to explain the possible association between VDT use and spontaneous abortion: physical stress (defined as prolonged sitting), workplace psychological stress, and electromagnetic energy emissions. There is little in the existing literature describing the risk of spontaneous abortion for these potential risk factors. Physical stress defined as heavy lifting has been associated with increased risk of spontaneous abortion.[17] However, an association with sitting or standing has not been observed.[17] The effect of workplace psychological stress on fetal loss has not been studied, although the effect of these stressors was examined in two studies which showed an association between a measure of occupational mental stress and premature birth.[18-19] A VDT containing a cathode-ray tube to generate a visual display emits both extremely low frequency (ELF) and very low frequency (VLF) fields. ELF electromagnetic fields have been associated with spontaneous abortion in two studies.[20-21] Both studies showed a seasonal pattern of spontaneous abortion in families with electrically heated beds[20] or ceiling cable electric heat.[21] Human studies of VLF electromagnetic fields and spontaneous abortion are limited primarily to studies of VDTs.[6-16]

This study examines the hypothesis that electromagnetic energy emissions from the VDT might cause spontaneous abortions. A future report will evaluate other potential adverse reproductive effects of VDT use. By selecting two groups of full-time female telephone operators with similar work situations, we intended to minimize the potential effect of physical and psychological workplace stress. One group, the directory assistance (DA) operators, who provided telephone numbers, used VDTs. The comparison group, the general operators, who provided assistance when "0" was dialed, did not use VDTs. VDT use was determined from personnel records maintained by the two study companies. Measurements of electromagnetic energy were conducted at a sample of DA and general operator locations.

METHODS

Study Population

The study population consisted of women employed as telephone operators at two companies in eight southeastern states. Typically, the DA operators used VDTs for the 8 1/2-hour work day, minus 1 hour for lunch and two 15-minute breaks. Their task was to provide telephone numbers to customers who called for assistance. A computer automatically routed incoming calls to the next available operator, so the time between calls was usually less than a second. Operators were monitored both by a computer which recorded the number of calls received per day and

the length of the time spent on each call, and by supervisors. Fifty DA offices in the eight state study area were in operation during the study period (1983-1986). Each office employed between 25 and 60 operators.

The general operators were the comparison group, whose duties were similar to those of the DA operators. However, general operators used a light emitting diode (LED) or neon glow tube (NGT) to display the numbers rather than a VDT. The general operators mainly assisted customers in placing long distance calls. Their workday was also 8 1/2 hours minus 1 hour for lunch and two 15-minute breaks. The general operators were also monitored by a computer and by their supervisors. Like the DA operators, calls were automatically routed to the next available operator so that the time between calls was usually less than a second. Approximately 36 general operator offices in the eight state study area were in operation during the study period. Each office employed between 40 and 60 operators.

Prior to January 1984, the regional company hired operators into DA or general positions as needed. After this date, the general operators were transferred to the former parent company. The two businesses now operated independently, but had similar hiring practices. Both DA and general operator positions required the same educational level and the salaries were similar. Both operator jobs required sitting in front of their respective equipment for the entire workday, both included customer contact, and both were monitored electronically and by their supervisors. While there may have been some differences in work practices between the two groups, we did not observe any. The primary difference was the presence or absence of the VDT.

Recruitment of Study Subjects

To maximize the number of pregnancies in the study population, a woman was eligible for participation in the study if she was 1) in the reproductive age group 18-33 (born after June 30, 1953) and 2) married at any time during the study period. In addition, to be eligible a woman had to be employed full-time at any time between January 1, 1983 and August 1, 1986 as a DA operator or general operator. We used employment records obtained from the study companies to identify women who met study age and employment eligibility criteria. We also used company records to obtain work history data including job titles, and dates of employment in those job titles. Women who were born after June 30, 1953 and had worked full-time as either a DA or general operator during the study period were telephoned at home and asked to participate in the study. Because the employment records did not include marital status, our first question was whether the woman had been married at any time during the study period. If she had been married, she was asked to participate in the study.

Current/last known addresses and phone numbers were obtained from the company records. Addresses were confirmed with the Internal Revenue Service and the U.S. Postal Service. We found that current telephone numbers in company records were often missing or outdated, and could not be obtained from directory assistance services. When we could not obtain a current phone number from company records, we instituted two additional methods to obtain valid phone numbers of potential participants. For those women currently employed by the two telephone companies, we called the workplace and asked the woman for her home telephone number. We then arranged to conduct the telephone interview at a later time. For those women who were no longer employed by the telephone companies, trained field interviewers contacted potential study participants at their home address to explain the study and to obtain a

valid phone number. The interview was conducted by the telephone interview staff at a later time. This field tracing effort was limited to 9 metropolitan areas, which included 74% (N=858) of the former employees we had been unable to contact. The remaining 26% who had moved to another region of the country or resided outside the major metropolitan areas were not contacted by the field interviewers.

Telephone Interview

A home telephone interview averaging 25 minutes was conducted by trained interviewers between July 1987 and August 1988. The study was described as a pregnancy outcome study among office workers to both the interviewers and potential participants. We collected lifetime reproductive histories including the outcome of all pregnancies inside and outside the study period. For each pregnancy in the study period, consumption of alcohol and cigarettes, use of medications and treatments, and any medical conditions were recorded.

Definition of a Study Pregnancy

Of the pregnancies reported in the interview, only those pregnancies which met the following eligibility criteria were included in the study: 1) the pregnancy resulted in a live birth, stillbirth (fetal loss after 28 weeks gestation) or spontaneous abortion (fetal loss of 28 weeks gestation or less); 2) the pregnancy terminated between January 1, 1983 and December 31, 1986 for spontaneous abortions, or between May 1, 1983 and December 31, 1986* for live births and stillbirths; 3) the operator was employed for at least 1 day as a DA operator or general operator during the first 28 weeks of pregnancy.

The beginning and ending dates of pregnancy were derived from the interview. The estimated last menstrual period was considered the beginning date for each pregnancy. Pregnancies of two women who reported using an intrauterine device at the time of conception were excluded from the study because of the high rate of spontaneous abortion among women who become pregnant while using this method of contraception.

Validation of Spontaneous Abortions

To identify possible recall differences in subject-reported outcome data, we collected state vital records on each reported live birth during the study period. We then compared the number of previous terminations reported on the confidential section of the birth certificate with the number reported in the interview for each operator group. In addition, we asked each woman if she had seen a physician for her spontaneous abortion and conducted a separate analysis of only those spontaneous abortions reported to a physician. We also attempted to obtain medical

*The latest eligibility date for livebirths and stillbirths had originally been April 30, 1987. However, after December 1986, VDTs began to be introduced into the general operator offices. Since general operator pregnancies after this date would have been exposed to VDTs, only those pregnancies terminating on or before December 31, 1986 were eligible for the study.

records for all spontaneous abortions during the study period but so few women provided permission to obtain the records that this effort was dropped.

Definition of VDT Use

We determined VDT use from company personnel and payroll records. Because DA operators exclusively used VDTs and had no other duties, while general operators exclusively used LED/NGT units and had no other duties, company records on dates of employment as a DA or general operator allowed objective classification of VDT use. In combination with the interview data on dates of pregnancy, we used personnel records to determine whether the pregnancy was exposed or unexposed.

We defined VDT use in three ways. First, we defined VDT use as a dichotomous variable (Yes or No). Pregnancies in which the mother worked as a DA operator at any time during the first trimester (defined as the first 13 weeks of pregnancy) were classified as exposed. Pregnancies in which the mother worked only as an general operator in the first trimester were classified as unexposed.

Second, to examine a dose-response relation, we used weekly payroll records to calculate hours of VDT use for each study pregnancy. From payroll records, we calculated the actual hours of VDT work for each trimester of pregnancy. Information regarding actual hours worked was crucial because the hours a woman worked with a VDT varied depending upon the stage of pregnancy when hired, the timing of vacations, the amount of sick leave used and the number of hours worked in a given day. For pregnancies where the woman worked as a DA operator, we constructed two continuous exposure indices using the data on her hours worked during the pregnancy. For the first index, we examined her hours of VDT use in the first trimester, the period of greatest risk for spontaneous abortion. To calculate this exposure index, we divided the woman's hours of VDT use during the first trimester by the total number of first trimester hours for that pregnancy. We then multiplied this ratio by the constant 168 hours per week to obtain her weekly hours of VDT use. A pregnancy which terminated early had fewer hours of VDT use (numerator), as well as a smaller denominator.

$$\text{Hours of VDT use per week} = \frac{\text{Hours of VDT use during first trimester}}{\text{Hours of pregnancy during first trimester}} \times \frac{168 \text{ hours}}{\text{week}}$$

For the second index, we calculated her hours of VDT use during the entire period of risk for an spontaneous abortion according to our study definition (first 28 weeks of gestation). In this second index, we divided her hours of VDT use during the first 28 weeks of gestation by the total number of hours the woman was pregnant in those first 28 weeks and multiplied by 168 hours per week. Pregnancies where the mother worked only as an general operator in the first trimester or first 28 weeks were assigned zero hours of VDT use.

Third, we also defined subject-reported VDT use (yes/no) according to responses obtained during the interview. Pregnancies in which the mother reported working with a video display terminal during the pregnancy were considered exposed for the subject-reported VDT use definition. Pregnancies in which the mother reported no use were considered unexposed.

Analytic and Statistical Methods

We defined the spontaneous abortion rate as the number of reported spontaneous abortions divided by the total reported spontaneous abortions plus reported live births. Multiple logistic regression analysis[22] was used to assess the effect of VDT use on spontaneous abortion while controlling for potential confounders. Variables were considered for the initial model if the preliminary stratified analysis suggested significance ($p<0.10$), or if the variable was an a priori potential confounder. Variables were retained if they were associated with a p-value of 0.10 or less, or if retention caused a substantial change (approximately 10%) in the exposure coefficient. All potential confounders and retained variables from the initial model were examined for potential interaction with VDT exposure.

The logistic model was run using the measures of VDT use defined above: 1) work as a DA or general operator (dichotomous); 2) hours per week of VDT use in the first trimester; 3) hours per week of VDT use in the first 28 weeks; and 4) subject-reported VDT use (dichotomous). In addition, we conducted separate analyses for early (8 weeks or less) and late (9 weeks to 28 weeks) spontaneous abortion. Also, analyses were performed that included stillbirths and excluded spontaneous abortions not reported to a physician.

A problem with the analysis of pregnancy outcome studies is that the outcomes of each woman are not independent events. To address this problem of correlated outcomes, we performed additional analyses for each VDT exposure measure as proposed by Zeger and Liang.[23] In these analyses, a class of generalized estimating equations takes into account the correlation of pregnancy outcomes within the same woman and adjusts odds ratios and their corresponding standard errors. This approach has the additional advantage of permitting covariates to change with each pregnancy.

Electromagnetic Energy Characterization

We measured the X-radiation and electromagnetic fields emitted by a sample of the VDT, LED, and NGT units used by the operators. Using previous measurement data on ELF and VLF field strengths and induced current,[24] we determined that 24 of each VDT model and 24 of each non-VDT model were needed to obtain a representative sample of the majority of VDT and non-VDT units.

Only two VDT models were used by the DA operators during the study period: International Business Machines (IBM) Model 4978, and Computer Consoles, Inc. (CCI) Model 4500. In 1990, we visited 8 of 50 DA offices and measured 6 randomly selected VDTs per site, for a total of 48 units (24 IBM and 24 CCI units). Only a single LED model and a single NGT model, both made by Western Electric, had been used by the comparison population during the study period. LED and NGT technology had not changed since it was introduced into the general operator offices in the 1960s. After December 1986, the end of the study period, VDTs began to be introduced into the general operator offices. Thus, in 1990, when we conducted a measurement survey of the LED and NGT equipment, we disabled all VDTs so that only LED and NGT emissions were measured. Because disabling the VDTs would have interfered with emergency calls handled by the general operator offices, LED and NGT measurements had to be conducted outside the study area at two midwest offices. These midwest offices had facilities

which allowed them to accommodate our requirements without interrupting emergency services. Measurements were done on 24 LED and 24 NGT units randomly selected at each site.

A cathode ray tube based VDT can generate several types of electromagnetic radiation including X-radiation, and electric (E)-fields and magnetic (H)-fields in both the ELF and VLF regions. To detect X-ray emissions, an X-ray monitor (Stoms meter) was passed over every accessible surface of VDT and non-VDT units. Background measurements were also made in several locations at each office. A Victoreen Model 440/RFC* ionization chamber meter was available for measuring the exposure rate of any X-rays detected. The magnitude of E-fields and H-fields was measured with two field strength meters (Holaday Industries Models HI 3600-01 and HI 3600-02). With the operator absent, the VLF and ELF emissions were measured at a distance of 30 cm from each of the six accessible surfaces of the unit. While the operator was seated at her terminal, exposure measurements were taken at her face, chest and abdomen.

When an electric field interacts with the operator's body, a current is induced that flows between the body and a grounded surface. We measured this current by connecting a microammeter between the operator's wrist and ground. The VDT chassis or a metallic surface on the work station served as ground. Detailed VLF and ELF measurements were conducted on one of the six randomly selected units at each site. These measurements included spatial variation of the E- and H-field strengths between 10-100 cm from the screen face and the rate of change of the VLF magnetic flux density per unit time (dB/dt).[25] Geometric means (GM) and geometric standard deviations (GSD) were calculated on emission, exposure, and induced current data for all IBM, CCI, LED and NGT units.

RESULTS

Figure 1 shows the process for selecting the final 882 study pregnancies from the initial 5,544 women identified from company records. Of 5,544 subjects identified from company records, 45 (0.8%) subjects were ineligible due to death, residence outside of the U.S., or incorrect identification of the potential subject as female; 19.3% could not be contacted (Table 1). Of the 4,475 women contacted, 4,246 (94.9%) agreed to participate (76.6% of the women initially identified). Both operator groups had similar participation rates (DA operators = 78.3%, general operators = 75.0%). Women who agreed to participate were slightly older at interview than women who did not participate (mean = 28.6 vs 27.8 years); employed for more years at the study companies (mean = 6.3 vs 3.8 years); and more likely to be white (55.7% vs 50.6%). Of the 4,246 women who agreed to participate, 2,430 had been married during the study period and were interviewed (Figure 1).

Of the women we interviewed, 730 had eligible study pregnancies, namely those which occurred while the mother was employed as either a DA or an general operator (Figure 1). Demographic characteristics of the 730 study women given in Table 2 show that the eligible women in the two operator groups were similar in mean age, mean lifetime number of pregnancies, race, education, percent currently employed at a study company, and mean years employed by a study company. The proportion of Hispanic women, however, differed between the two groups (2.8% of DA operators and 8.6% of general operators).

*Mention of commercial equipment does not constitute endorsement by NIOSH.

The 730 study women had 882 eligible study pregnancies which included 16 sets of twins. Pregnancy outcomes are shown in Table 3. The proportions of live births, spontaneous abortions, and stillbirths were similar among DA and general operators. The overall crude spontaneous abortion rate among all reported pregnancies was 14.8% among VDT exposed pregnancies and 15.9% among the comparison pregnancies. In both groups, the spontaneous abortion rate was highest in the second and third month of gestation (Figure 2).

When we calculated the spontaneous abortion rate by actual hours of weekly VDT use in the first trimester, we observed a slightly greater but nonsignificant spontaneous abortion rate for VDT use of 1-25 hours per week (17.2%) compared to 0 hours per week (15.6%) (Table 4). The pregnancies with greater than 25 hours of VDT exposure had a similar spontaneous abortion rate to those pregnancies with 0 hours of VDT use (15.4% and 15.6%, respectively). A similar pattern was observed when we examined hours of VDT use during the first 28 weeks of gestation.

The final multiple logistic regression model included the dichotomous VDT exposure variable, spontaneous abortion prior to the study period, cigarette smoking, thyroid disorder and alcohol consumption (Table 4). This analysis showed no association between VDT use in the first trimester and an increased risk of spontaneous abortion (OR=0.93, 95% CI=0.63-1.38). When we substituted the other two record-based VDT exposure variables (hours of VDT use in the first trimester and hours of VDT use in the first 28 weeks) into the model, we also found no increased risk (Table 4). The category-specific odds ratios for weekly hours of VDT use (none, 1-25 hours/week and greater than 25 hours/week) showed no association between risk of spontaneous abortion and increasing hours of VDT use (Table 4). We also modeled the hours per week of VDT use as a continuous variable. This also produced nonsignificant results. Additionally, when we substituted subject-reported VDT use for the record-based VDT use variables, we observed no effect (OR=0.85, 95% CI=0.56-1.29).

Only 17.1% (N=125) of women had more than one study pregnancy. The maximal number of study pregnancies per woman was 4 (N = 6 women). Adjustment for multiple pregnancies per woman using the correlated outcome methodology of Zeger and Liang[23] did not significantly affect the coefficients of our final models (odds ratio for dichotomous VDT exposure = 0.94, 95% CI=0.61-1.44).

Logistic regression analyses of early and late spontaneous abortion substituted into the final model showed no significant differences. The odds ratio for early spontaneous abortion was 0.84 (95% CI=0.51-1.38). The odds ratio for late spontaneous abortion was 1.05 (95% CI=0.58-1.88). When all fetal losses, including the 9 stillbirths that occurred after 28 weeks gestation were examined in the final model, there was a negligible change in the odds ratio for VDT use (OR=0.99, 95% CI=0.68-1.44). When we eliminated the 10 spontaneous abortions that were not reported to a physician, we found minimal change in the odds ratio (OR=0.90, 95% CI=0.61-1.35).

Although our analyses demonstrated no significant association between VDT use and spontaneous abortion, we found that several other factors were associated with an altered risk of spontaneous abortion (Table 4). In both univariate and logistic regression analyses we found a history of spontaneous abortion, cigarette smoking, thyroid disorder, and greater than 8 alcoholic drinks/month during pregnancy increased the risk of spontaneous abortion. Drinking 1-8 drinks/month was associated with a lower risk of spontaneous abortions than for

nondrinkers (spontaneous abortion rate 4.9% and 16.6%, respectively; OR=0.24, CI=0.11-0.53). The coefficients for these factors did not vary substantially when we substituted different VDT use variables into the model. The exclusion of these factors individually or in combination did not change the relation between VDT use and spontaneous abortion.

Variables which did not meet inclusion criteria for the logistic model included age at conception, maternal race and ethnicity, and prior induced abortion. Three factors which met our criteria for addition to the model were not retained for a number of reasons. Gestational age at first prenatal visit was not included as a potential confounder since an early first prenatal visit may be associated with symptoms of spontaneous abortion. Similarly, nausea was not included since it may be a symptom of a successful pregnancy. The use of antibiotics during the pregnancy appeared to be negatively associated with spontaneous abortion. However, because we did not obtain trimester-specific antibiotic usage, the observed association could be an artifact of different length of gestation for spontaneous abortions and live births. Inclusion or exclusion of these variables did not alter the estimated relation between VDT use and spontaneous abortion.

Based upon *a posteriori* power calculations, the final logistic model had 80% power to detect an odds ratio of 1.65 or greater for an spontaneous abortion-VDT association. This method of calculating power after completion of an analysis takes into account the influence of other covariates in the model upon the exposure odds ratio and its standard error.[26]

The background ionizing radiation relative count rate at the study sites ranged from 20-400 cpm. Background levels did not differ between VDT and non-VDT sites. None of the ionizing radiation measurements taken at the surface of the VDT and non-VDT units differed from background levels. The VDTs in this study emitted ELF at 45 Hz (CCI) and 60 Hz (IBM) and VLF in the 15 kHz range. Typical results of the ELF field, VLF field and induced current measurements are shown in Table 5. Geometric means for VLF field frontal emissions and abdominal exposures were statistically higher for the VDT compared to non-VDT units ($p<0.05$). The NGT and LED displays do not produce VLF fields above instrumentation background levels. The rate of change of the VLF magnetic flux density for the VDT units ranged between 9.0 and 38.0 milliteslas per second (mT/s). While ELF emissions were significantly higher for VDT units compared to the LED/NGT units, there was substantial overlap in individual ELF measurements of operator exposure. When we examined the spatial variation of the ELF fields, we found that the electrical environment in the room contributed to the field strength of the ELF fields.[25] The VDTs produced significantly greater induced currents than non-VDT displays. A complete report of measurement data is provided by Tell.[25]

Because mean VLF and ELF measurements for the CCI terminal were, in some comparisons, higher than the IBM terminal measurements, we conducted an additional logistic regression analysis which included separate exposure variables for pregnancies exposed to CCI and IBM terminals. This analysis showed no difference in spontaneous abortion risk for women using a CCI unit (OR=0.92, 95% CI=0.58-1.47) and those using an IBM unit (OR=0.98, 95% CI= 0.58-1.64). When we conducted a direct comparison of IBM and CCI terminals, excluding the unexposed pregnancies, we observed no significant increased risk for IBM terminals (OR=1.05, 95% CI=0.57-1.92).

DISCUSSION

In this study we found no increase in the risk of spontaneous abortion associated with occupational VDT use. After adjusting for confounders, an increased risk was not observed with the three record-based VDT use measures; with self-reported VDT use; with type of VDT model used; or after accounting for multiple pregnancies per woman. Separate analyses of early spontaneous abortion, late spontaneous abortion, all fetal losses, and spontaneous abortions confirmed by a physician also failed to identify an increased risk of spontaneous abortion associated with VDT use. While the upper confidence limit on the odds ratio of 1.39 cannot exclude a modest positive association, there were no other indications of a causal association such as a trend with increasing hours of VDT use.

The overall spontaneous abortion rate among the VDT users (14.8%) and the comparison group (15.9%) were within the range of published data (11%-20%).[27] While we found no association between VDT use and spontaneous abortion, significant associations were found for three risk factors previously reported in the literature: prior spontaneous abortion, cigarette smoking and the presence of a thyroid disorder.[27-29]

The association of alcohol consumption with spontaneous abortion in other studies has not been totally consistent, but suggests an adverse effect of moderate to heavy alcohol consumption during pregnancy, which our study confirms.[27,28,30] The association of spontaneous abortion with light alcohol consumption has been studied less, with inconsistent results.[27,28,30] In our study, we found a reduced risk among light drinkers compared to non-drinkers. Interpretation of alcohol consumption from retrospective interview data is difficult because women change their drinking habits during pregnancy[31] and may have difficulty recalling exactly when this change occurred. In the analysis of our data, it is more important to note that the inclusion or exclusion of the alcohol use variables did not change the relation between VDT use and spontaneous abortion.

Because pregnancy outcome information was reported by the women themselves, there was the possibility of recall differences between the two groups. Confirmation of spontaneous abortion was limited because in the states comprising the study population, vital records data were not available for spontaneous abortions. The 2,430 interviewed women reported a total of 203 spontaneous abortions between 1983-1986. The mothers of 77 (38%) of these spontaneous abortions had subsequent live births which provided the opportunity to confirm prior spontaneous abortions from information recorded on the live birth certificate. Analysis of birth certificates for pregnancies terminating between January 1, 1983, and December 31, 1986, showed that 89% (49/55) of spontaneous abortions reported by general operators and 86% (19/22) of spontaneous abortions reported by DA operators were recorded in subsequent vital records. We discovered only one spontaneous abortion that had not been reported in the interview. While we were able to review only those spontaneous abortions which were followed by a live birth (38% of all spontaneous abortions), the consistent findings in both the exposed and comparison groups argue against differential recall of spontaneous abortions as a logical explanation for our negative findings.

Differences in the rates or timing of induced abortions between the exposed and comparison group are unlikely explanations for our negative findings. The rates of induced abortion among the VDT exposed (4.8%) and comparison (5.3%) pregnancies were similar, as was the gestational age at the time of the induced abortion (mean number of weeks at abortion = 9.6 and 7.9, respectively). We plotted Kaplan-Meier estimators and found that when we included

induced abortions as censored events, there was no significant difference between spontaneous abortion survival distributions (i.e., no difference in the week of gestation during which the spontaneous abortion occurred) for VDT exposed and comparison pregnancies (Logrank X^2 = 0.32, p = 0.57).

Because we had a slightly different ascertainment period for livebirths and stillbirths (May 1, 1983 - December 31, 1986) than for spontaneous abortions (January 1, 1983 - December 1, 1986), our study contained proportionally fewer fullterm pregnancies during the later months of 1986. If the two operator groups had a differential number of pregnancies during the later months of 1986, the number of spontaneous abortions in one group could be artificially increased. To examine this, we reanalyzed the data eliminating the 11 spontaneous abortions occurring after April 30, 1986, and found no increased risk (odds ratio = 0.86, 95% CI = 0.57-1.30).

Differences in VDT use outside the workplace is not a likely explanation for our findings. We examined data on home VDT usage reported in the interview and found that only 1.9% of VDT exposed pregnancies and 2.2% of unexposed pregnancies involved exposure at home.

When we compared payroll records with data on VDT use provided in the interview, we found that approximately 52% of the general operators who did not use a VDT while pregnant, reported such use. Only 4% of DA operators who used a VDT while pregnant reported no use. A likely reason for overreporting by the general operators is that they may have mistakenly referred to LED/NGT equipment as a VDT in the interview. If this is the reason for overreporting, studies of different populations might have fewer errors in self-reported VDT use than documented here. However, the discrepancy between self-reported and record-based VDT use indicates that the accuracy of self-reported data may vary.

Elements of the study design did not allow us to address certain other questions directly. First, we could not assess whether early (subclinical) fetal loss might be affected by VDT use. The data shown in Figure 2, however, suggest that the incidence of the earliest recognized losses was similar for the exposed and unexposed pregnancies. Secondly, we could not assess the effects of VDT use on older or unmarried women since our study was limited to married women age 18-33. Such women make up the majority of pregnant women in the U.S. Third, we studied a population that used only two models of VDT. Electromagnetic fields produced by the VDTs in our study were similar to those reported for other VDTs, however.[24,32,33] Finally, we selected the DA and general operators because of the similar levels of physical and psychological stress in their jobs. Therefore, this study could not address the potential association between spontaneous abortion and physical or psychological stress--two factors that may accompany VDT use.

Although concern has been expressed that VDTs may produce harmful levels of electromagnetic energy, our research found that VDT operators had abdominal exposure to ELF fields (45-60 HZ) in the same range as exposures in the home. Studies of ELF exposures found average home magnetic field exposures to be between 40 mA/m and 200 mA/m[34-36] and average electric field exposures to be 2.5 V/m.[36] While ELF emissions at 30 cm from the VDTs were significantly higher than non-VDT units, the VDT operator's abdominal ELF exposure was only slightly higher than the non-VDT operator's exposure. In fact, there was substantial overlap in exposure levels for individual VDT and non-VDT operators and both fell within the range of the home exposures cited above. We found H-field geometric means between 32.4 and 62.4 mA/m

and E-field geometric means between 0.4 and 0.8 V/m. These data indicate that the magnitude of ELF magnetic field exposure received by some VDT operators is not substantially different from background levels. While VDT operators were exposed to VLF fields (15 kHz), LED and NGT units used by the general operators produced no measurable emissions in this range.

The strengths of this study include the similarity of the VDT user group and the comparison group, the use of record-based data on the extent of VDT use during each pregnancy, and the direct measurement of electromagnetic fields. When we examined our data for potential biases, we found none that were likely to have substantively influenced the results. We conclude that VDT use and exposure to the electromagnetic fields they produce were not associated with an increased risk of spontaneous abortion in this study.

A future report will evaluate other potential adverse reproductive effects of VDT use.

ACKNOWLEDGEMENTS

We thank the women who gave their time to participate in this study. We are also indebted to Patricia Dill, Edith Dodd, William Ehling, Jean Geiman, Christine Gersic, Frances Guerra, Barbara Jenkins, M.A., Kathy Masterson, Susan Nowlin, Andrea Okun, M.S., Richard Tell, M.S., Mary Torok, Dwight Werran, and Harvey Zelon, M.S.P.H. for their support and expertise.

REFERENCES

1. Berquist UO. Video display terminals and health: A technical and medical appraisal of the state of the art. Scand J Work Environ Health 1984; 10:Suppl 2:62-67.

2. Binkin N, Rochat RW, Cates W, Tyler CW. Cluster of spontaneous abortions, Dallas, Texas. 1981. Centers for Disease Control, Atlanta, Georgia. (EPI 80-113-2).

3. National Institute for Occupational Safety and Health: Health Hazard Evaluation 84-297-1609, General Telephone Company of Michigan, Alma, Michigan. 1984. (NTIS publication no. PB86-143609).

4. National Institute for Occupational Safety and Health: Health Hazard Evaluation 83-329-1498, Southern Bell, Atlanta, Georgia. 1983. (NTIS publication no. PB85-208379).

5. National Institute for Occupational Safety and Health: Health Hazard Evaluation 84-191, United Airlines, San Francisco, California. 1984.

6. Ericson A, Kallen B. An epidemiological study of work with video screens and pregnancy outcome: I. A registry study. Am J Ind Med 1986; 9:447-457.

7. Ericson A, Kallen B. An epidemiological study of work with videoscreens and pregnancy outcome: II. A case-control study. Am J Ind Med 1986; 9:459-475.

8. Nurminen T, Kurppa, K. Office employment, work with video display terminals, and course of pregnancy. Scand J Work Environ Health 1988; 14:293-298.

9. Kurppa K, Holmberg PC, Rantala K, Nurminen T, Saxen L. Birth defects and exposure to video display terminals during pregnancy. Scand J Work Environ Health 1985; 11:353-356.

10. Westerholm P, Ericson A. Pregnancy outcome and VDU-work in a cohort of insurance clerks. In: Knave B, Wideback PG, eds. Work with display units 86: Selected papers from the International Scientific Conference on Work With Display Units, Stockholm, Sweden, May 12-15, 1986. Amsterdam, North-Holland: Elsevier Science Publishers B.V., 1987; 104-110.

11. Bryant HE, Love EJ. Video display terminal use and spontaneous abortion risk. Int J Epidemiol 1989; 18(1):132-138.

12. Nielsen CV, Brandt LPA. Spontaneous abortion among women using video display terminals. Scand J Work Environ Health 1990; 16:323-328.

13. Brandt LPA, Nielsen CV. Congenital malformations among children of women working with video display terminals. Scand J Work Environ Health 1990; 16:329-333.

14. Windham GC, Fenster L, Swan SH, Neutra RR. Use of video display terminals during pregnancy and the risk of spontaneous abortion, low birthweight, or intrauterine growth retardation. Am J Ind Med 1990; 18:675-688.

15. McDonald AD, McDonald JC, Armstrong B, Cherry N, Nolin AD, Robert D. Work with visual display units in pregnancy. Brit J Ind Med 1988; 45:509-515.

16. Goldhaber M, Polen M, Hiatt R. The risk of miscarriage and birth defects among women who use visual display terminals during pregnancy. Am J Ind Med 1988; 13:695-706.

17. Goulet L, Theriault G. Association between spontaneous abortion and ergonomic factors, a literature review of the epidemiologic evidence. Scand J Work Environ Health 1987; 13:399-403.

18. Mamelle N, Laumon B, Lazar P. Prematurity and occupational activity during pregnancy. Am J Epidemiol 1984; 119:309-322.

19. Mamelle N, Munoz F. Occupational working conditions and preterm birth: a reliable scoring system. Am J Epidemiol 1987; 126:150-152.

20. Wertheimer N, Leeper E. Possible effects of electric blankets and heated waterbeds on fetal development. Bioelectromagnetics 1986; 7:13-22.

21. Wertheimer N, Leeper E. Fetal loss associated with two seasonal sources of electromagnetic field exposure. Am J Epidemiol 1989; 129(1):220-224.

22. Harrell FE. The Logist Procedure. SUGI Supplemental Library User's Guide, Version 5 Ed. Cary, North Carolina: SAS Institute, 1986.

23. Zeger SL, Liang K-Y. Longitudinal data analysis for discrete and continuous outcomes. Biometrics 1986; 42:121-130.

24. Guy AW. Measurement and analysis of electromagnetic field emissions from 24 video display terminals in American Telephone and Telegraph Office, Washington, D.C. A report prepared for the National Institute for Occupational Safety and Health, Cincinnati, Ohio, 1987.

25. Tell R. An Investigation of electric and magnetic fields and operator exposure produced by VDTs: NIOSH VDT epidemiology study, final report. National Institute for Occupational Safety and Health, Cincinnati, Ohio. 1990. (NTIS publication no. PB91-130500).

26. Petersen MR. Post study power estimation by computer. J Statis Comput 1988; 29:195-210.

27. Kline J, Stein Z, Susser M. Conception to birth - epidemiology of prenatal development. Monographs in Epidemiology and Biostatistics, Vol. 14, 1989. New York, Oxford: Oxford University Press.

28. Harlap S, Shiono P. Alcohol, smoking and incidence of spontaneous abortions in the first and second trimester. Lancet 1980; ii:173-176.

29. Potter JD. Hypothyroidism and reproductive failure. Surg Gynecol Obstet 1980; 150(2):251-255.

30. Kline J, Shrout P, Stein Z, Susser M, Warburton D. Drinking during pregnancy and spontaneous abortion. Lancet 1980; ii:176-180.

31. Russell M, Skinner JB. Early measures of maternal alcohol misuse as predictors of adverse pregnancy outcomes. Alcoholism Clin Exper Res 1988; 824-830.

32. Stuchly MA, Lecuyer DW, Mann RD. Extremely low frequency electromagnetic emissions from video display terminals and other devices. Health Physics 1983; 45:713-722.

33. Guy AW. Health hazards assessment of radio frequency electromagnetic fields emitted by video display terminals. In. Knave B, Wideback PG, eds. Work with display units 86: Selected papers from the International Scientific Conference on Work With Display Units, Stockholm, Sweden, May 12-15, 1986. Amsterdam, North-Holland: Elsevier Science Publishers B.V., 1987; 69-80.

34. Barnes FS, Wachtel H, Savitz D. Measurements of the distribution of 60 Hz fields in residences. Annual Meeting of Bioelectromagnetics Society. June 16-20, 1985. San Francisco, CA.

35. Tell RA. Instrumentation for measurement of radio frequency electromagnetic fields: equipment, calibrations and selected applications. Part I - Radiofrequency fields. In: Grandolfo M, Michaelson SM, Rindi A, eds. Biological effects and dosimetry of non-ionizing radiation: Radiofrequency and microwave energies. New York: Plenum Press, 1983; 95-162.

36. Bowman JD, Garabrant DH, Sobel E, Peters JM. Exposures to extremely low frequency (ELF) electromagnetic fields in occupations with elevated leukemia rates. Appl Ind Hyg 1988; 3:189-194.

Table 1

Response Rate of Potential Study Participants
According to Job Category*

	DA Operator(%)	General Operator(%)	Total(%)
Agreed to Participate	2118 (78.3)	2128 (75.0)	4246 (76.6)
Unable to Contact	483 (17.9)	586 (20.6)	1069 (19.3)
Ineligible	21 (0.8)	24 (0.8)	45 (0.8)
Refused	83 (3.1)	101 (3.6)	184 (3.3)
TOTAL	2705(100.1)	2839(100.0)	5544(100.0)

* DA operators used VDTs in their work, whereas general operators did not. Because of rounding, percentages may not total 100.

Table 2

Characteristics of Study Participants
with Eligible Pregnancies According to Job Category*

	DA Operators (N = 323)	General Operators (N = 407)
Mean Age (in years)+	29.6	29.6
Mean Lifetime No. Pregnancies	2.6	2.6
Mean Years Worked at Study Companies	8.2	7.7
Currently Employed at Study Companies (%)+	50.8	57.0
White (%)	71.5	68.3
Hispanic (%)	2.8	8.6
More than a High School Education (%)	28.9	35.3

* DA operators used VDTs in their work, whereas general operators did not.

+ on 7/1/87

Table 3

Outcome of Eligible Study Pregnancies
According to Job Category*

Pregnancy Outcome	DA Operator Pregnancies (%)	General Operator Pregnancies (%)	Total Pregnancies (%)
Live births	307 (83.9)	430 (83.3)	737 (83.6)
Stillbirths	5 (1.4)	4 (0.8)	9 (1.0)
Spontaneous Abortions	54 (14.8)	82 (15.9)	136 (15.4)
TOTAL	366 (100.1)	516 (100.0)	882 (100.0)

* DA operators used VDTs in their work, whereas general operators did not. Because of rounding, percentages may not total 100.

Table 4

Unadjusted Rates of Spontaneous Abortion and Adjusted Odds Ratios for Occupational VDT Use and Other Variables in the Final Logistic Model*

Variable		# Pregnancies	SAB+ Rate (95% CI)	OR for SAB (95% CI)	p-value
Spontaneous Abortion before Study Period	No	709	12.8 (10.3-15.3)	1.0 (-)	
	Yes	167	25.7 (19.1-32.3)	1.64 (0.98-2.77)	0.06
No. Alcoholic Drinks/Month					
	None	716	16.6 (13.9-19.3)	1.0 (-)	
	1-8	143	4.9 (1.4- 8.4)	0.22 (0.10-0.49)	<0.01
	>8	17	47.1 (23.4-70.8)	2.81 (0.99-8.04)	0.05
Cigarettes/Day					
	None	671	14.2 (11.6-16.8)	1.0 (-)	
	1-19	144	14.6 (8.8-20.4)	1.09 (0.64-1.84)	.76
	≥20	61	29.5 (18.1-40.9)	2.89 (1.50-5.56)	<0.01
Thyroid Disorder (Diagnosed during or before 1st Trimester)					
	No	853	14.8 (12.4-17.2)	1.0 (-)	
	Yes	23	34.8 (15.3-54.3)	2.75 (1.09-6.94)	0.03
VDT Use in 1st Trimester					
	No	510	15.7 (12.5-18.9)	1.0 (-)	
	Yes	366	14.8 (11.2-18.4)	0.93 (0.63-1.38)	0.73
Other VDT Exposure Variables Substituted into Final Model					
Hours/Week VDT Use-1st Trimester++					
	None	499	15.6 (12.4-18.8)	1.0 (-)	
	1-25	128	17.2 (10.7-23.7)	1.04 (0.61-1.79)	0.88
	>25	169	15.4 (10.0-20.8)	1.00 (0.61-1.64)	0.99
Hours/Week VDT Use-1st 28 Weeks++					
	None	494	15.8 (12.6-19.0)	1.0 (-)	
	1-25	119	18.5 (11.5-25.5)	1.18 (0.69-2.04)	0.54
	>25	179	14.5 (9.3-19.7)	0.90 (0.55-1.47)	0.67

* Odds ratios compare the odds of spontaneous abortion for a pregnancy with the specified risk factor to the odds of spontaneous abortion for a pregnancy without that risk factor. Each odds ratio is adjusted for all the other risk factors in the model.

\+ SAB denotes spontaneous abortion.

++ When these VDT exposure variables were substituted into the model, confounder coefficients did not vary substantially and the VDT-SAB relation remained unchanged. The total number of pregnancies varied in each analysis due to missing data.

Table 5

Geometric Mean (GM) and Standard Deviation (GSD)
of Electromagnetic Energy Measurements

	Very Low Frequency(VLF)				Extremely Low Frequency(ELF)			
	E-Field(V/m)		H-Field(mA/m)		E-Field(V/m)		H-Field(mA/m)	
Unit Type	GM	(GSD)	GM	(GSD)	GM	(GSD)	GM	(GSD)
Frontal Emissions (Operator Absent)								
VDT								
CCI	4.2	(1.54)*	98.9	(2.61)*	1.9	(1.63)*	313.6	(1.22)*
IBM	3.3	(2.07)	22.1	(4.68)	1.8	(1.93)	236.1	(2.14)
Non-VDT								
LED	0.1	(1.16)	1.6	(1.01)	0.4	(1.10)	72.3	(1.68)
NGT	0.1	(2.05)	1.4	(1.04)	0.5	(1.40)	30.3	(1.72)
Abdominal Exposure (Operator Present)								
VDT								
CCI	0.5	(1.68)*	17.4	(1.74)*	0.8	(3.61)*	62.3	(1.59)
IBM	0.1	(1.71)	4.0	(1.85)	0.4	(1.70)	57.7	(2.12)
Non-VDT								
LED	0.1	(1.35)	2.0	(1.15)	0.4	(1.18)	62.4	(2.79)
NGT	0.2	(1.64)	1.6	(1.00)	0.4	(1.92)	32.4	(2.01)

Keyboard Induced Current (uA)		
Unit Type	**GM**	**(GSD)**
VDT		
CCI	4.13	(4.415)*
IBM	0.38	(4.650)
Non-VDT		
LED	0.01	(1.009)
NGT	0.02	(1.021)

* $p<0.05$ for the difference between VDT (IBM and CCI units) and non-VDT (LED and NGT units).

FIGURE 1
Selection of Study Participants

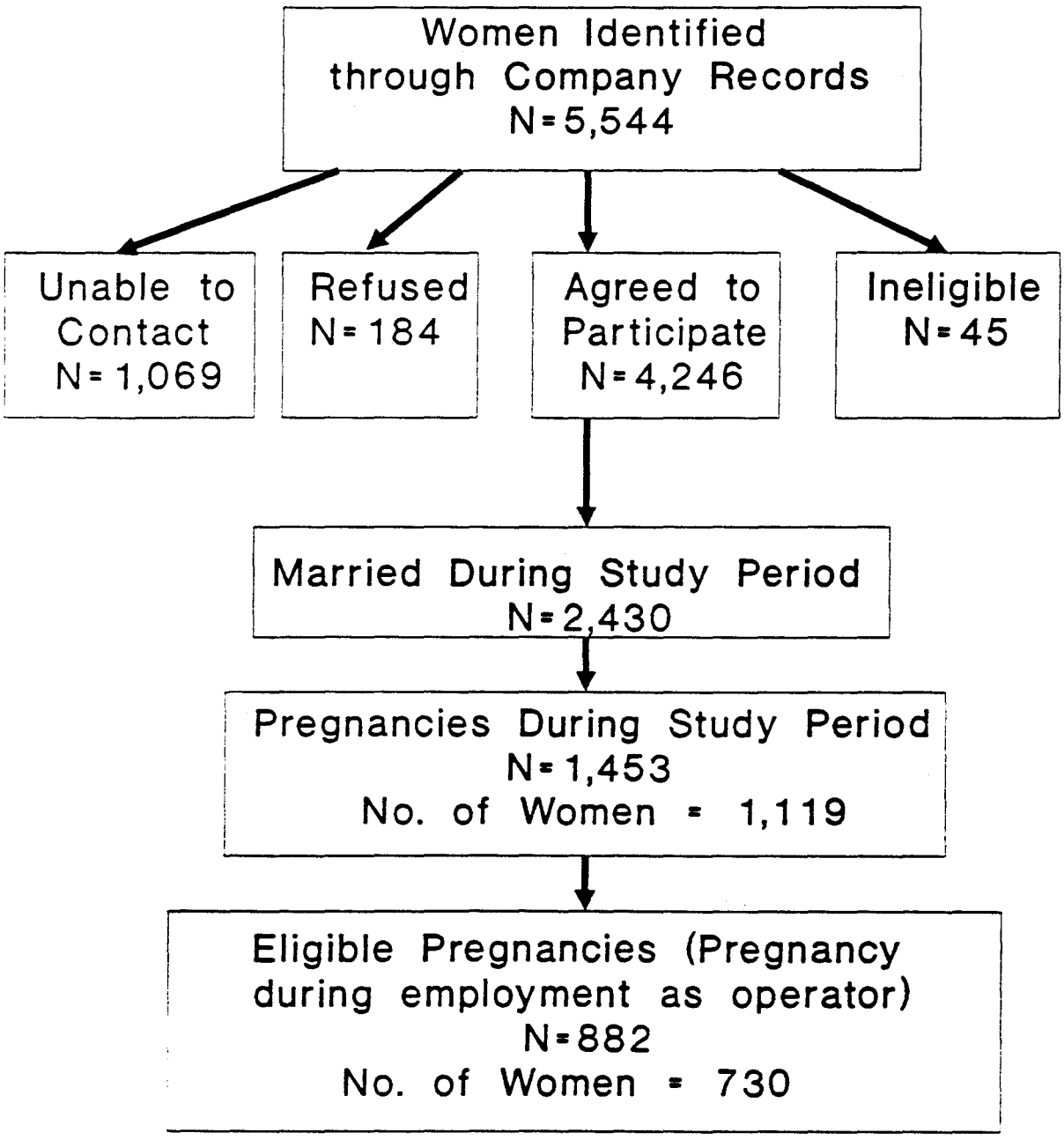

FIGURE 2

Spontaneous Abortion Rate by Gestational Age and VDT Exposure Category