Video display terminal use during pregnancy and reproductive outcome—a meta-analysis

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Abstract

Study objective—The aim was to obtain quantitative information from published data on the potential association between video display terminal (VDT) use during pregnancy and the outcome.

Design—Results of nine published case-control studies (or cohort studies analysed as case-control) on the relation between VDT exposure during pregnancy and the outcome were sought by reviewing reference lists in relevant reports and by conducting manual and computer searches of the reports published in English.

Measurements and main results—The nine reviewed reports included information on about 9000 cases of spontaneous miscarriages, 1500 of low birth weight, 2000 of congenital malformation, and 50 000 controls. The results of these studies on each outcome of pregnancy examined were reduced to a single 2×2 table (cases/controls—exposed/unexposed). Pooled odds ratio (OR) estimates were computed separately for miscarriage, low birth weight, and congenital malformation. Seven studies analysed the relation between VDT exposure in pregnancy and the risk of miscarriage: the estimates' crude OR of spontaneous abortion ranged from 0.9–1.2 and the pooled OR was 1.0 (95% confidence interval (CI) 0.9, 1.0). No consistent evidence of increasing risk with duration of exposure to VDT was found. Two studies analysed the relation between VDT use and risk of having a low birth weight infant: the OR estimates in the individual studies were 1.0 and 1.1. Likewise, no relation emerged from the five studies providing information on congenital malformations and VDT use: the pooled OR was 1.0 (95% CI 0.9, 1.2). No specific malformation pattern emerged.

Conclusions—This meta-analysis provides reassuring evidence on the absence of any major risk of adverse pregnancy outcome as a result of exposure to a VDT. With the number of cases reviewed, it was possible to exclude excess risk of 20% for spontaneous abortion, low birth weight, and congenital malformations.

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taneous abortions and birth defects in pregnant women using visual display terminals (VDT) received widespread attention in the scientific and lay press, particularly in the United States and Canada.^{1,2} Animal data partially supported these suggestions. Damage to chick embryos or fetal malformations in mice were reported after exposure to pulsed electromagnetic and magnetic fields.^{3–5}

Because of the large number of women exposed to VDT or other common electrical equipment such as televisions, electric typewriters and domestic appliances which are sources of electromagnetic fields, even a limited risk of adverse outcome of pregnancy may constitute a considerable public health issue.

Several formal analytical epidemiological studies have been published on this subject. The present report aimed to review their results to obtain quantitative pooled estimates of the potential association between VDT use and various outcomes of pregnancy.

Methods

The results of published case-control studies (or cohort studies analysed as case-control studies) on the relation between VDT exposure and pregnancy outcome were sought by reviewing reference lists in relevant reports and by conducting manual and computer (MEDLINE) searches of the papers published in English. A total of nine articles were retrieved^{6–14} (two of which were based on the same study^{7,8}). The results of these studies on each outcome of pregnancy examined were reduced to a single 2×2 table (cases/controls—exposed/unexposed). Pooled odds ratio (OR) estimates were computed separately for miscarriage, low birth weight, and congenital malformation.

STATISTICAL TECHNIQUES

Standard methods for the combination of information from 2×2 tables were used. The expected number of cases exposed to VDT (E) and the variance (V) of the difference between the observed (O) and expected number of cases were computed using the usual procedure described by Mantel and Haenszel.¹⁵ The trend in risk was assessed using the test given by Mantel.¹⁶ If exposure was completely without effect on the risk of the disease, the quantity (O–E) with variance V (and hence with standard error $\sqrt{V}$) would differ only randomly from zero. If it were associated with the disease, however, the quantity (O–E) would tend to be positive, and although in any particular study this tendency might be obscured or even reversed by the effect of chance, it should stand

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The potential adverse consequences of exposure to electromagnetic fields during pregnancy has been a topic of scientific and public health interest since the middle 1970s, when clusters of spon-

out clearly when the grand total (GT) of the (O-E) values from several independent studies was examined. If the factor were unrelated to the disease, this grand total would itself differ only randomly from zero, with variance equal to the sum of individual variances (SIV), and hence standard error $\sqrt{\text{SIV}}$. If, in addition, it is assumed that any real effect of VDT exposure is not heterogeneous in different studies, then the odds ratio (OR) in exposed compared with unexposed subjects is estimated by exponential (exp) (GT/SIV), with an approximate 95% confidence interval (CI=exp (GT/SIV)±1.96 SIV).

Examination of these statistics is based on the assumption that data from all studies have been included without any material bias caused by unavailability of negative results or biased selection of cases and controls. However, it does not assume implicitly that subjects in one study can be compared directly with subjects in another, but it is based entirely on comparison of the cases in each study with their own controls.

Results

The main characteristics of the studies considered are shown in table I. Most were initially designed in the early 80s as cohort investigations of preg-

nant women to evaluate the effect of several occupational exposures on reproductive outcomes. Nested case-control analyses for the relation between VDT exposure and pregnancy outcome were subsequently performed following suggestions from the published reports. The definition of exposure was generally based on self-reporting. In one study the interview data were checked according to the information retrieved from company personnel records. The level of exposure was defined in term of the average number of hours per week.

SPONTANEOUS ABORTIONS

Seven studies analysed the relation between VDT exposure in pregnancy and the risk of miscarriage, including more than 4000 cases of spontaneous abortions and about 30 000 controls. The prevalence of exposure in controls varied widely from less than 20% in the largest study conducted on working women in Canada¹² to more than 50% in a case-control analysis nested in a cohort study conducted in Sweden.⁹ The estimated OR for spontaneous abortion ranged from 1.0 to 1.2 and the pooled OR was 1.0 (95% CI, 0.9, 1.0, table II). A significantly increased risk (OR 1.5) of miscarriage in the first trimester in women exposed to VDT was reported in one study.¹⁴ No other study

Table I Main characteristics of studies considered in the review

Author, country, study period	Type of study	Outcomes considered	Selection of Cases	Controls	Definition of exposure
Bryant and Love; Canada, 1984–1985 ⁶	Case-control	SA	SA (<20 weeks' gestation) admitted in a network of collaborating hospitals	Two control groups: (a) prenatal: women <25 weeks gestation identified from prenatal class list (interviewed at home or in the office) (b) post partum: women delivering healthy infants in the same hospitals as cases.	Self-reported (interview)
Brandt and Nielsen; Nielsen and Brandt; Denmark, 1983–1985 ^{7, 8}	Case-control	SA, CM	SA or CM in women members of the Danish Union of Commercial and Clerical Employees.	"Random" sample of normal deliveries reported in the same population as cases.	Self-reported (postal questionnaire; response rate 76% for cases and 75% for controls).
Ericson and Källén; Sweden, 1980–1981 ⁹	Case-control nested in a cohort	SA, CM, LBW (<1500g)	SA, CM, LBW reported in three cohorts of women at professional high, medium, and low probability of using VDT	Sample of women with favourable reproductive outcome in the same cohorts as cases	Self-reported (postal questionnaire, response rate 99%).
Goldhaber <i>et al</i> ; USA, 1981–1982 ¹⁰	Case-control nested in a cohort	SA and CM	SA and CM reported in a cohort of women self-referring for pregnancy testing at three Kaiser Permanente Medical Care Programs	Random sample (20%) of normal deliveries in the cohort	Self-reported (postal questionnaire and for non-responders interview by phone) overall response rate 83% for SA, 88% for CM and controls)
Kurppa <i>et al</i> ; Finland, 1976–1982 ¹¹	Population based case-control	CM	Sample of cases reported to the National Register of Congenital Malformations	Women who delivered immediately before the cases in the same maternity health care district	Self-reported (interview during the mother's first post-natal visit)
McDonald <i>et al</i> ; Canada, 1982–1984 ¹²	Case-control	SA, LBW (<2500g) CM	SA, LBW, CM in women with professional high probability of using VDT	Normal delivery in woman at professional high probability of using VDT	Self-reported (interview in hospital)
Schnorr <i>et al</i> ; USA, 1983–1986 ¹³	Case-control	SA	Married women aged 18–33 employed as directory assistants or general telephone operators who reported SA	Women who reported normal pregnancy	Personal records and interview data
Windham <i>et al</i> ; USA, 1986–1987 ¹⁴	Case-control	SA, LBW (<2500g)	Women who had a SA by 20 weeks' gestation, for which a pathology specimen was submitted to a network of hospitals.	Women who had a live birth matched with cases by last menstrual period and hospital. LBW were compared with normal controls.	Self-reported (telephone interview, response rates 73% and 81% respectively cases and controls).

SA=spontaneous abortions; CM=congenital malformations; LBW=low birth weight

Table II Main results from selected studies on spontaneous abortion (SA) and video display terminal (VDT) use

Authors	SA (exposed/total)	Controls (exposed/total)	Odds ratio (95% CI)	Comments
Bryant and Love ⁶	140/334	151/314*	0.8 (0.6, 1.1)	No change after adjustment for covariates
Ericson and Kallen ⁹	208/327	127/333† 572/926	1.2 (0.9, 1.6) 1.1 (0.8, 1.4)	No change after taking into account major covariates
Goldhaber <i>et al</i> ¹⁰	115/355	213/723	1.1 (0.9, 1.5)	No change after adjustment for covariates
McDonald <i>et al</i> ¹²	361/1763 415/4887	4711/24 614‡ 2164/22 517§	1.1 (1.0, 1.2) 0.9 (0.8, 1.0)	–
Nielsen and Brandt ⁷	353/666	421/764	0.9 (0.7, 1.1)	No marked difference in OR in an analysis stratified for major potential covariates.
Schnorr <i>et al</i> ¹³	54/134π	312/742	0.9 (0.6, 1.4)	No excess risk among women who used VDT in the first trimester of pregnancy.
Windham <i>et al</i> ¹⁴	239/439	461/909	1.2 (0.9, 1.5)	No change after adjustment for covariates. OR=1.5 in the first trimester of pregnancy.
Total	1885/8905	9005/51 509	1.0 (0.9, 1.0)	

*Prenatal controls, included in the pooled analysis; †postnatal controls, not included in the pooled analysis; ‡current pregnancies; §previous pregnancies; πEstimated from percentages.

analysed separately the risk of spontaneous abortion according to gestational age. Potential covariates were taken into account in most analyses: no appreciable differences were observed between crude and adjusted estimates.

An increasing risk with duration of exposure to VDT was found in one study.¹⁰ In another,¹² there was a direct trend in risk with duration of VDT exposure for the current, but not for previous pregnancies. No significant association was observed in the remaining five studies and the pooled trend in risk was not statistically significant (χ^2 trend 0.55, table III).

LOW BIRTH WEIGHT

Two studies analysed the relation between VDT use and the risk of giving birth to an infant of low birth weight (defined as ≤ 2500 g) for a total of over 1500 cases and 21 000 controls (table IV). The OR estimates in the individual studies ranged from 0.5 to 1.1, with a pooled OR of 1.0 (95% CI 0.9, 1.2). In one study, an increasing risk of low birth weight with hours/week of VDT use was observed, but this finding was not statistically significant.¹⁴

Table III Odds ratios of spontaneous abortions according to level of video display terminal (VDT) exposure (defined as h/week). (Figures in parenthesis are number of case:controls.)

Authors	Level of exposure			χ^2 trend
	No VDT use	Low (≤ 20 h/wk)	High (≥ 20 h/wk)	
Bryant and Love ⁶	1++ (191:175)*	0.8 (102:121)	1.0 (21:18)	0.72 (p=ns)
Ericson and Kaller ⁹	1++ (119:354)	1.00 (125:360)	1.2 (73:177)	1.19 (p=ns)
Goldhaber <i>et al</i> ¹⁰	1++ (240:510)	0.9 (63:148)	1.7 (52:65)	3.82 (p=0.05)
McDonald <i>et al</i> ¹²	1++ (1402:18 501)†	1.0 (177:2243)	1.2 (184:2107)	2.96 (p=ns)
Nielsen and Brandt ⁷	1++ (4472:15 885)‡	1.0 (249:859)	0.7 (166:890)	16.74 (p<0.001)§
	1++ (316:356)	1.0 (273:319)	1.0 (77:89)	
Schnorr <i>et al</i> ¹³	1++ (78:421)*	1.1 (22:106)	1.0 (26:143)	0.00 (p=ns)
Windham <i>et al</i> ¹⁴	1++ (200:448)	1.2 (109:207)	1.1 (130:254)	1.18 (p=ns)
	1++ (7018:36 650)	1.0 (1120:4363)	1.0 (729:3743)	
Total				0.55 (p=ns)

++Reference category. *Prenatal controls; numbers estimated from percentages. They are generally consistent, but not exactly consistent, with those published in Table II. †Current pregnancies. ‡Previous pregnancies. §In the original paper the trend was not significant after adjustment of year of conception.

CONGENITAL MALFORMATIONS

No relation emerged from five studies that provided information on congenital malformation and VDT use: the pooled OR based on about 2000 cases and 50 000 controls was 1.0 (95% CI 0.9, 1.2, table V). An increased risk of cardiac malformation, renal malformation, or hydrocephalus was reported from some studies, but these findings were not confirmed. Likewise, an increased risk of aspecific malformation with increasing exposure to VDT was seen in one study⁹ but not in others.^{8 11}

PRETERM BIRTH AND PERINATAL MORTALITY

The relation between preterm births, perinatal mortality, and VDT exposure in pregnancy was analysed in three studies.^{9 12 14} No association emerged.

Discussion

The results of this meta-analysis of published epidemiological studies are largely reassuring and indicate that VDT use during pregnancy is not associated with any material risk of miscarriage, low birth weight, or congenital malformation. No consistent trend in risk was observed with duration of exposure to VDT and no specific pattern of malformation emerged in women exposed to electromagnetic fields from a VDT. Fewer data are available on the effect of VDT on perinatal mortality, but the scanty figures showed no convincing relationship.

We considered only unadjusted estimates in the computation of the pooled OR. In the individual studies, however, multivariate estimates, including terms for major potential covariates (such as smoking habits or socioeconomic indicators), were in general consistent with crude ones.

Although the studies reviewed differ in terms of study population, type of exposure, and methods of data collection, the OR estimates in individual studies were generally comparable, and, in any case, not statistically heterogeneous, giving strong evidence of the consistency of the pooled results.

In the interpretation of the results of meta-analysis, publication bias is one of the major issues. In this case, however, it is unlikely that such a bias plays a major role. Epidemiological studies in this field are generally large and expensive, and tend therefore to be published independently from their results. Furthermore, negative results are also of interest for publication, given the public health relevance of the issue.

Most studies considered only exposure at work to minimise the bias related to the potential association of VDT use with pregnancy risk because of psychological stress associated with some occupations.^{1 17–19} No difference emerged, however, in OR estimates from hospital based case-control or cohort studies including women who were not working. Whichever study design is considered, moreover, it is likely that any bias in exposure assessment tends to overestimate the true association, since cases may systematically remember better their potential sources of exposure.

It has been suggested that it is difficult to define exposure to VDT, since the extremely low frequency magnetic fields produced do not diminish

Table IV Main results from reports that selected low birth weight (LBW) and video display terminal use.

Authors	LBW (exposed/total)	Controls (exposed/total)	Odds ratio (95% CI)	Comments
McDonald <i>et al</i> ¹²	288/1501	4034/21 180	1.0 (0.9, 1.2)	No change after adjustment for covariates. No trend in risk with increasing exposure.
Windham <i>et al</i> ¹⁴	34/64	411/816	1.1 (0.7, 1.9)	No change after adjustment for covariates. OR for >20 h/wk exposure 1.4 (95% CI 0.8, 2.5)
Total	322/1565	4445/21 996	1.0 (0.9, 1.2)	

appreciably with distance from the displays—that is, the ambient fields in an office are per se a source of exposure to electromagnetic fields.^{20 21} Similar considerations should hold for domestic exposure. Furthermore, electromagnetic fields due to VDT exposure are minimal and generally not significantly above background levels.²² Other sources of electromagnetic fields may constitute greater risks for reproduction²³ and the contribution of VDT may therefore be irrelevant. This overview therefore is largely reassuring with regard to the effect of VDT use and pregnancy outcome, but it is not possible to exclude any potential effects from other sources of electromagnetic fields. Another possible drawback of published studies is the absence of information on subclinical miscarriages, but early concern about the reproductive hazards of VDT was raised after identification of clusters of clinically recognised miscarriages. In general, any definition, and hence risk assessment, of chemical or physical risk factors for subclinical miscarriage is always extremely difficult.

Table V Main results from selected studies on congenital malformations (CM) and video display terminal use.

Authors	CM (exposed/total)	Controls (exposed/total)	Odds ratio (95% CI)	Comments
Brandt and Nielsen ⁸	137/421	456/1365	1.0 (0.8, 1.2)	No change after adjustment for covariates. No trend in risk with increasing exposure. OR for hydrocephalus 12.0 (95% CI 1.4, 104.0).
Ericson <i>et al</i> ⁹	72/102	572/926	1.6 (1.0, 2.4)	No specific pattern of CM; significant trend in risk with number of hours of exposure to VDT. OR 2.0 for 10h/week and 2.3 for >20h/week.
Goldhaber <i>et al</i> ¹⁰	32/97	213/723	1.2 (0.7, 1.9)	No change after adjustment for covariates. OR 1.4 for >25h/wk exposure. No specific pattern of CM
Kurppa <i>et al</i> ¹¹	51/235	601/255	0.9 (0.6, 1.4)	No trend in risk with increasing exposure. OR for cardiovascular defects 1.6 (95% CI 0.7, 3.9)
McDonald <i>et al</i> ¹²	103/627* 55/572†‡	4628/26 755 1702/19 699	0.9 (0.8, 1.2) 1.1 (0.8, 1.5)	OR for renal/urinary organs 1.8 (p 0.02) in current pregnancies.
Total	451/2054	6330/49 723	1.0 (0.9, 1.2)	

*Current pregnancies; †Previous pregnancies; ‡In the birth defects groups the authors also included a few infants without malformation who had died and very low birth weight infants (<1500g)

In conclusion, the present overview provides important reassurance on the absence of any major adverse risk during pregnancy from exposure to VDT, since with the number of cases reviewed, it was possible to exclude an excess risk of 20% for spontaneous abortion, low birth weight, and congenital malformation.

1 Bergqvist 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: 1-87.

2 Landrigan PJ, Melius JM, Rosenberg MJ, Coye MJ, Binkin NJ. Reproductive hazards in the workplace. Development of epidemiologic research. *Scand J Work Environ Health* 1983; **9**: 83-8.

3 Delgado JMR, Leal J, Montegaudo JL, Gracia MG. Embryological changes induced by weak, extremely low frequency electromagnetic fields. *J Anat* 1982; **134**: 533-51.

4 Ubeda A, Leal J, Trillo MA, Jimenez MA, Delgado JM. Pulse shape of magnetic fields influences chick embryogenesis. *J Anat* 1983; **137**: 513-36.

5 Sikov MR, Rommezein DN, Beamer JS, *et al*. Development studies of Hanford miniature swine exposed to 60-Hz electrical fields. *Bioelectromagnetics* 1977; **8**: 229-42.

6 Bryant HE, Love EJ. Video display terminal use and spontaneous abortion risk. *Int J Epidemiol* 1989; **18**: 132-8.

7 Nielsen CV, Brandt LPA. Spontaneous abortion among women using video display terminals. *Scand J Work Environ Health* 1990; **16**: 323-8.

8 Brandt LPA, Nielsen CV. Congenital malformations among children of women working with video display terminals. *Scand J Work Environ Health* 1990; **16**: 329-33.

9 Ericson A, Källén B. An epidemiological study of work with video screens and pregnancy outcome: II. A case-control study. *Am J Ind Med* 1986; **9**: 459-75.

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

11 Kurppa K, Holmberg PC, Rantala K, Nurminen T, Saxen L. Birth defects and exposure to video display terminals during pregnancy. A Finnish case-referent study. *Scand J Work Environ Health* 1985; **11**: 353-56.

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

13 Schnorr TM, Grajewski BA, Hornung RW, *et al*. Video display terminals and the risk of spontaneous abortion. *N Engl J Med* 1991; **324**: 727-33.

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**: 675-88.

15 Mantel N, Haenszel W. Statistical aspects of the analysis of data from retrospective studies of disease. *J Natl Cancer Inst* 1959; **22**: 719-48.

16 Mantel N. Chi-square tests with one degree of freedom: extension of the Mantel-Haenszel procedure. *J Am Stat Assoc* 1963; **58**: 690-700.

17 Johansson G, Aronsson G. Stress reactions in computerized administrative work. *J Occup Behav* 1980; **5**: 159-81.

18 Smith M, Cohen B, Sammerjohn L. An investigation of health complaints and job stress in video display operations. *Hum Factors* 1981; **23**: 387-400.

19 Tenaka T., Fukumoto T. The effects of VDT work on urinary excretion of catecholamines. *Ergonomics* 1988; **31**: 1753-63.

20 Slesin L, Connolly M. Video display terminals and spontaneous abortions. *N Engl J Med* 1991; **325**: 811-2.

21 Tell R. *An investigation of electric and magnetic fields and operator exposure produced by VDTs: NIOSH VDT epidemiology study, final report*. Cincinnati: National Institute for Occupational Safety and Health, 1990. (NTIS publication no. PB91-500).

22 Bureau of Radiologic Health. *An evaluation of radiation emission from video display terminals*. US Dept of Health and Human Services. HHS publ FDA 1981; **81**: 8153.

23 Werthmeier N, Leeper E. Fetal loss associated with two seasonal sources of electromagnetic field exposure. *Am J Epidemiol* 1989; **129**: 220-4.