international journal of andrology ISSN 0105-6263

ORIGINAL ARTICLE

Use of cellular and cordless telephones and risk of testicular cancer

L. Hardell,*† M. Carlberg,* C.-G. Ohlson,‡** H. Westberg,†‡ M. Eriksson§ and K. Hansson Mild†¶

*Department of Oncology, University Hospital, Örebro, †Department of Natural Sciences, Örebro University, Örebro, ‡Department of Occupational and Environmental Medicine, University Hospital, Örebro, §Department of Oncology, University Hospital, Lund, ¶National Institute for Working Life, Umeå, and **Institution of Clinical Medicine, Örebro University, Örebro, Sweden

Keywords:
case–control study, non-seminoma, seminoma, wireless communication

Correspondence:
Lennart Hardell, Department of Oncology, Örebro University Hospital, SE-701 85 Örebro, Sweden. E-mail: lennart.hardell@orebroll.se

Received 26 June 2006; revised 5 September 2006; accepted 11 September 2006

doi:10.1111/j.1365-2605.2006.00721.x

Summary

A case–control study on testicular cancer included use of cellular and cordless telephones. The results were based on answers from 542 (92%) cases with seminoma, 346 (89%) with non-seminoma, and 870 (89%) controls. Regarding seminoma the use of analog cellular phones gave odds ratio (OR) = 1.2, 95% confidence interval (CI) = 0.9–1.6, digital phones OR = 1.3, CI = 0.9–1.8, and cordless phones OR = 1.1, CI = 0.8–1.5. The corresponding results for non-seminoma were OR = 0.7, CI = 0.5–1.1, OR = 0.9, CI = 0.6–1.4, and OR = 1.0, CI = 0.7–1.4, respectively. There was no dose–response effect and OR did not increase with latency time. No association was found with place of keeping the mobile phone during standby, such as trousers pocket. Cryptorchidism was associated both with seminoma (OR = 4.2, CI = 2.7–6.5) and non-seminoma (OR = 3.3, CI = 2.0–5.6), but no interaction was found with the use of cellular or cordless telephones.

Introduction

In Sweden the annual age-adjusted incidence of testicular cancer increased significantly by 1.7% ($p < 0.02$) using trend test during the time period 1985–2004 (National Board of Health and Welfare, 2006). An increasing incidence of testicular cancer has also been reported from several other Western countries during the last decades (Toppari *et al.*, 1995; Bray *et al.*, 2006). It is the most common cancer among young males.

The aetiology of testicular cancer is not fully known and it is usually not regarded as an occupational disease. Cryptorchidism is one established risk factor (Henderson *et al.*, 1979; Schottenfeldt *et al.*, 1980). Perinatal exposure, e.g., to persistent organic pollutants (POPs) with hormone activity (xenoestrogens) has been suggested to be another risk factor. During recent decades there has also been an increasing incidence of male developmental reproductive disorders. Testicular cancer, cryptorchidism, hypospadia and low sperm count have been grouped together in the testicular dysgenesis syndrome and may have common aetiological risk factors (Skakkebæk *et al.*, 2001). We have reported an increased concentration of certain POPs in mothers of patients with testicular cancer compared with mothers of control subjects (Hardell *et al.*, 2003, 2004a, 2006a). This finding gives support to the hypothesis that exposure to POPs during the fetal period is a risk factor for testicular cancer.

In a case–control study on testicular cancer and various occupational exposures we observed a sixfold increase in the risk for testicular cancer, mainly seminoma, among men exposed to polyvinyl chloride (PVC) plastics indicating that exposure in adult life might also influence the risk (Hardell *et al.*, 1997; Ohlson & Hardell, 2000). However, in a larger follow-up study we found only a slightly increased risk of testicular cancer after exposure to PVC-containing materials (Hardell *et al.*, 2004b; Westberg *et al.*, 2005). Detailed assessments of the individual exposures did not indicate a dose–response relationship, but rather an inverse relationship with the highest odds ratios (OR) in the lowest exposure category. The OR increased somewhat with increasing latency time. This inverse relationship between exposure to PVC and OR did not clearly indicate an increased risk for testicular cancer despite the overall increased risk as strengthened by taking latency into account. However, it should be noted

that many hormone-disrupting chemicals exhibit an inverted U dose–response curve, e.g., certain phytoestrogens (Almstrup *et al.*, 2002).

There has been some concern in the population that exposure to microwaves in the radiofrequency fields (RF) during mobile phone calls may be a risk factor for testicular cancer, especially if the phone is located in a pocket close to the testis. Some exposure to microwaves occurs in that situation during phone calls but only to a very low extent during standby of the phone (contact signal with the base station). In a recent study a genotoxic effect on epididymal spermatozoa was reported in mice exposed to 900 MHz microwaves (Aitken *et al.*, 2005). In a human study on semen quality and mobile phone use some negative effect on the sperm motility characteristics was found (Fejes *et al.*, 2005). In a review of exposure to extremely low-frequency electromagnetic fields (below a few hundred Hertz) and risk of malignant diseases, no association with testicular cancer was found, but the data were limited (Hardell *et al.*, 1995).

Recently, there has been a rapid development in the use of wireless telephone communication. The Nordic countries were among the first in the world to introduce this new technology. During mobile phone calls microwaves in the RF field are emitted.

Exposure is characterized through the specific absorption rate (expressed as W/kg). Analog (NMT; Nordic Mobile Telephone System) phones operating at 450 MHz were introduced in Sweden in 1981. In the beginning they were usually used in a car with fixed external antenna. Portable NMT 450 phones were introduced in 1984. Analog phones using 900 MHz (NMT 900) were used in Sweden between 1986 and 2000. The digital system (GSM; Global System for Mobile Communication) started in 1991 and has, during recent years, dramatically increased to be the most common type of phone. This system uses dual bands, 900 and 1800 MHz, for communication. From 2003 the third-generation mobile phones, 3G or UMTS (Universal Mobile Telecommunication System) started in Sweden operating at 1900 MHz.

Desktop cordless phones use wireless technology. The analog system in the 800–900 MHz RF was used when these phones were available in Sweden in 1988. Digital cordless telephones (DECT) that operate at 1900 MHz are in use since 1991.

In the case–control study on exposure to PVC plastics (Hardell *et al.*, 2004b; Westberg *et al.*, 2005) we also included the same questions on use of cellular and cordless telephones as in studies on brain tumours performed during the same time (Hardell *et al.*, 2006b,c). The concerned research ethics committee approved the study. In this article we present results for the use of cellular and cordless telephones and the risk of testicular cancer.

Materials and methods

Subject ascertainment

All cases of testicular cancer (ICD 7 code 178) aged 20–75 years in the whole Swedish male population in the years 1993–1997 were identified in the Swedish Cancer Registry. In total, 1061 cases were reported. Of these, 37 were deceased (only living cases were included), 18 had a benign tumour and three had cancer in situ. Only germ cell tumours were included and 15 cases with other histopathological types of testicular cancer were excluded. The doctors in charge of the cases were contacted and asked for permission to include the patient in the study. Four cases were excluded due to e.g., Down's syndrome. Furthermore, three cases had unknown addresses. Consequently, the remaining study group consisted of 981 cases – 592 with seminoma and 389 with non-seminoma.

The controls were sampled from the Swedish Population Registry by selecting at random one subject to each case in the same 5-year age groups, i.e. 20–24, 25–29 years, etc., irrespective of the area of residence. Thus, the primary sample included 981 cases and 981 matched controls. This study was performed during 1999–2001.

The questionnaire was answered by 889 (91%) cases. One case was excluded due to missing data and the results were based on data from 542 (92% response frequency) cases with seminoma and 346 (89% response frequency) cases with non-seminoma. The response rate for controls was 870 (89% response frequency). The mean age was 36 years for cases and 37 years for controls; 40 years for the cases with seminoma and 30 years for the cases with non-seminoma.

Assessment of exposure

A letter of introduction and an 18-page questionnaire were sent to the cases and the controls. Reminders were sent to those who did not respond within 3 weeks and also a second time to the remaining non-responders. Lifetime working history and specific exposure to agents such as PVC, organic solvents, pesticides, insect repellents, asphalts, use of computers, etc. were enquired as reported previously (Hardell *et al.*, 2004b; Westberg *et al.*, 2005).

Regarding the use of cellular telephones, we asked about first year of use, type of phone (analog with prefix 010, digital with prefix 07), mean minutes of daily use over the years, use in a car with external antenna or a hands-free (both calculated as unexposed) and location of the phone during standby. Similar questions dealt with the use of cordless telephones, although without questions on location during standby.

The questionnaires were scrutinized by a specially trained interviewer and supplemented over the phone if

necessary. We gave all questionnaires an ID-code that did not show if it was a case or a control. Thus, interviews and coding of data for the statistical analysis were made blinded as to case or control status. Exposure ≤1 year before diagnosis was disregarded, hence the same year was used for the matched control and the corresponding case.

Statistical methods

Unconditional logistic regression analysis was used to calculate OR and 95% confidence intervals (CI), (Stata/SE 8.2 for Windows; StataCorp, College Station, TX, USA). We used this method due to low numbers in some of the calculations as it allowed us to also include all subjects in the analyses, including those in incomplete matched pairs. Subjects who had not used cellular or cordless phones were regarded as unexposed in the statistical calculations. The exposed cases and controls were divided according to the type of phone in question, i.e. analog, digital cellular telephones and cordless telephones. We also calculated OR and 95% CI for use of any of these phone types and for different combinations. Adjustment was made for age, cryptorchidism and year of diagnosis, hence the same year was used for the case and the corresponding control. Adjustment for year of diagnosis was made as the study included the years 1993–1997 and use of cellular and cordless telephones increased over the years. We used age as a continuous variable in the analysis. Latency or tumour induction period was analysed using three time periods: >1–5, >5–10 and >10 years since first use of a cellular or cordless telephone until diagnosis. In the dose–response calculations the median number of cumulative lifetime use in hours among controls was used as the cut-off, although in Table 1 it is based on tertiles among the controls. Note that the overall results for all latency groups were calculated in one analysis, whereas the dose–response was analysed separately for each latency category.

Results

Of the 542 responding seminoma cases, 125 (23%) reported use of an analog cellular phone, 98 (18%) a digital cellular phone and 104 (19%) a cordless phone. The corresponding results for the 346 non-seminoma cases were 50 (14%), 66 (19%) and 70 (20%) respectively. Regarding the 870 responding controls, 173 (20%) reported use of analog phones, 137 (16%) digital and 165 (19%) cordless phones.

In Table 1 results are given for the cumulative number of hours of use of the different phone types and in total. Increased OR was found for seminoma in the lowest cumulative exposure group (1–127 h) for use of analog mobile phones or cordless phones. However, OR decreased with increasing cumulative number of hours of use.

Table 1 Odds ratio (OR) and 95% confidence interval (CI) for cumulative lifetime use in hours (tertiles among controls) of analog and digital cellular telephones, cordless telephones and any combination of the three phone types

	1–127 h			128–547 h			>547 h		
	Ca/Co	OR	95% CI	Ca/Co	OR	95% CI	Ca/Co	OR	95% CI
Total									
Analog	102/78	1.3	0.9–1.8	46/62	0.7	0.5–1.04	27/33	0.8	0.5–1.4
Digital	85/66	1.2	0.8–1.8	48/46	0.9	0.6–1.5	31/25	1.1	0.6–1.9
Cordless	60/38	1.5	1.002–2.4	77/72	1.1	0.8–1.6	36/55	0.6	0.4–0.97
Total, any combination	135/120	1.1	0.9–1.5	142/124	1.1	0.8–1.4	93/114	0.8	0.6–1.04
Seminoma									
Analog	73/78	1.6	1.1–2.3	34/62	0.9	0.6–1.5	18/33	0.9	0.5–1.6
Digital	52/66	1.5	0.97–2.3	28/46	1.1	0.7–1.8	18/25	1.2	0.6–2.4
Cordless	37/38	1.7	1.1–2.9	46/72	1.2	0.8–1.8	20/55	0.6	0.4–1.1
Total, any combination	92/120	1.4	0.99–1.9	94/124	1.3	0.96–1.8	55/114	0.8	0.6–1.2
Non-seminoma									
Analog	29/78	1.0	0.6–1.6	12/62	0.5	0.2–0.9	9/33	0.8	0.3–1.7
Digital	33/66	1.0	0.6–1.6	20/46	0.9	0.5–1.6	13/25	1.0	0.5–2.1
Cordless	23/38	1.5	0.8–2.7	31/72	1.1	0.7–1.8	16/55	0.6	0.3–1.1
Total, any combination	43/120	0.9	0.6–1.3	48/124	0.9	0.6–1.3	38/114	0.7	0.5–1.1

Number of exposed cases (Ca) and controls (Co) are given. Unconditional logistic regression analysis adjusted for age, year of diagnosis and cryptorchidism was used. Test for trend yielded for analog phones $p = 0.03$, digital $p = 0.65$, cordless $p = 0.01$, any combination $p = 0.09$. For seminoma analog phones $p = 0.07$, digital $p = 0.62$, cordless $p = 0.02$, any combination $p = 0.04$; for non-seminoma analog phones $p = 0.15$, digital $p = 0.94$, cordless $p = 0.10$, any combination $p = 0.77$.

Table 2 Number of exposed cases (Ca) with testicular cancer and controls (Co), odds ratio (OR) and 95% confidence interval (CI) for use of cellular or cordless telephones. Unconditional logistic regression analysis adjusted for age, year of diagnosis and cryptorchidism was used. In the dose–response calculations median number of cumulative use in hours among controls in the total material was used as the cut-off

	>1–5 year latency		>5–10 year latency		>10 year latency		Total, >1 year latency	
	Ca/Co	OR (CI)	Ca/Co	OR (CI)	Ca/Co	OR (CI)	Ca/Co	OR (CI)
Total (n = 888, 515 unexposed)								
Analog	99/113	0.9 (0.6–1.2)	62/51	1.2 (0.8–1.8)	14/9	1.5 (0.6–3.7)	175/173	1.0 (0.8–1.3)
≤160 h	71/61	1.2 (0.8–1.7)	35/22	1.6 (0.9–2.8)	4/4	0.9 (0.2–3.8)	110/87	1.3 (0.9–1.7)
>160 h	28/52	0.5 (0.3–0.8)	27/29	0.9 (0.5–1.5)	10/5	2.1 (0.7–6.2)	65/86	0.7 (0.5–1.01)
Digital	154/134	1.1 (0.8–1.4)	10/3	2.8 (0.8–11)	0/0	–	164/137	1.1 (0.8–1.5)
≤182 h	91/70	1.2 (0.9–1.7)	5/0	–	0/0	–	96/70	1.3 (0.9–1.8)
>182 h	63/64	0.9 (0.6–1.3)	5/3	1.4 (0.3–6.4)	0/0	–	68/67	0.9 (0.6–1.3)
Cordless[a]	120/114	1.1 (0.8–1.4)	54/51	1.0 (0.7–1.6)	0/0	–	174/165	1.0 (0.8–1.4)
≤365 h[b]	95/71	1.4 (0.97–1.9)	34/25	1.3 (0.8–2.3)	0/0	–	129/96	1.4 (1.001–1.8)
>365 h[b]	24/43	0.5 (0.3–0.9)	20/26	0.7 (0.4–1.4)	0/0	–	44/69	0.6 (0.4–0.9)
Seminoma (n = 542, 299 unexposed)								
Analog	70/113	1.1 (0.8–1.5)	42/51	1.4 (0.9–2.1)	13/9	2.1 (0.8–5.1)	125/173	1.2 (0.9–1.6)
≤160 h	51/61	1.5 (0.99–2.3)	24/22	1.8 (0.98–3.4)	4/4	1.4 (0.3–5.9)	79/87	1.6 (1.1–2.2)
>160 h	19/52	0.6 (0.4–1.1)	18/29	1.0 (0.6–2.0)	9/5	2.6 (0.8–8.1)	46/86	0.9 (0.6–1.3)
Digital	92/134	1.3 (0.9–1.8)	6/3	3.9 (0.9–16)	0/0	–	98/137	1.3 (0.9–1.8)
≤182 h	56/70	1.5 (0.98–2.2)	3/0	–	0/0	–	59/70	1.5 (1.03–2.3)
>182 h	36/64	1.0 (0.7–1.6)	3/3	1.9 (0.4–9.7)	0/0	–	39/67	1.1 (0.7–1.7)
Cordless[a]	69/114	1.1 (0.8–1.6)	35/51	1.2 (0.7–1.9)	0/0	–	104/165	1.1 (0.8–1.5)
≤365 h[b]	56/71	1.5 (0.99–2.2)	23/25	1.6 (0.8–2.9)	0/0	–	79/96	1.5 (1.1–2.1)
>365 h[b]	12/43	0.5 (0.3–0.98)	12/26	0.8 (0.4–1.7)	0/0	–	24/69	0.6 (0.4–1.02)
Non-seminoma (n = 346, 216 unexposed)								
Analog	29/113	0.7 (0.4–1.1)	20/51	1.0 (0.5–1.8)	1/9	0.3 (0.04–2.6)	50/173	0.7 (0.5–1.1)
≤160 h	20/61	0.9 (0.5–1.6)	11/22	1.3 (0.5–2.9)	0/4	–	31/87	0.9 (0.6–1.5)
>160 h	9/52	0.4 (0.2–0.9)	9/29	0.8 (0.4–1.8)	1/5	0.9 (0.1–8.0)	19/86	0.6 (0.3–0.97)
Digital	62/134	0.9 (0.6–1.4)	4/3	2.0 (0.4–10)	0/0	–	66/137	0.9 (0.6–1.4)
≤182 h	35/70	1.0 (0.6–1.6)	2/0	–	0/0	–	37/70	1.0 (0.6–1.7)
>182 h	27/64	0.9 (0.5–1.5)	2/3	1.1 (0.2–7.5)	0/0	–	29/67	0.9 (0.5–1.4)
Cordless[a]	51/114	1.1 (0.7–1.6)	19/51	0.9 (0.5–1.6)	0/0	–	70/165	1.0 (0.7–1.4)
≤365 h[b]	39/71	1.4 (0.9–2.2)	11/25	1.2 (0.5–2.5)	0/0	–	50/96	1.3 (0.9–2.0)
>365 h[b]	12/43	0.6 (0.3–1.2)	8/26	0.7 (0.3–1.6)	0/0	–	20/69	0.6 (0.4–1.1)

[a]For two cases no information was obtained on the use of cordless phones, hence not included here.
[b]For one case cumulative number of hours is missing.

Table 2 gives the results for different latency periods. In total, regarding seminoma and the lowest exposure group, analog cellular phones gave OR = 1.6, CI = 1.1–2.2 (≤160 h), digital OR = 1.5, CI = 1.03–2.3 (≤182 h), and cordless phones OR = 1.5, CI = 1.1–2.1 (≤365 h). However, lower OR was calculated in the highest exposure group and there was no dose–response effect. For non-seminoma, no significantly increased OR was calculated. No subjects had used digital or cordless phones for >10 years. Regarding analog phones, the >10 year latency period yielded for seminoma OR = 2.1, CI = 0.8–5.1, increasing to OR = 2.6, CI = 0.8–8.1 in the highest exposure group. These results were, however, based on low numbers.

We analysed OR for use of the different types of phones only or in any combination (see Table 3) without any significantly increased risks. We also analysed the influence of age at first reported use of the phones. No significantly increased OR was found and age was not a determinant of the risk (data not shown).

The median cumulative number of hours for the mobile phone in standby was 17 520 h among the controls (Table 4). Somewhat increased OR were calculated in the >10 year latency group, but these results were based on rather low numbers and no dose–response effect was found. Regarding seminoma, OR = 1.3, CI = 1.03–1.7 was calculated in total for >1 year latency. In addition, subjects who had always used an external antenna in a car were included, although in the analysis of mobile phone use during calls, such use was regarded as no exposure.

In Table 5 results are displayed for keeping the mobile phone in different pockets of the clothes. No overall

Table 3 Number of exposed cases (Ca) with testicular cancer and controls (Co), odds ratio (OR) and 95% confidence interval (CI) for use of cellular or cordless telephones for different combinations of phone use. Unconditional logistic regression analysis adjusted for age, year of diagnosis and cryptorchidism was used

	>1 year latency		
	Ca/Co	OR	CI
Total			
Analog only	77/101	0.7	0.5–1.03
Digital only	88/71	1.2	0.8–1.7
Cordless only	85/88	1.0	0.7–1.4
Analog + Digital	52/40	1.3	0.8–2.0
Analog + cordless	65/51	1.2	0.8–1.8
Digital + cordless	44/45	0.9	0.6–1.5
Analog + Digital + cordless	20/19	1.0	0.5–2.0
Total, any combination	372/358	1.0	0.8–1.2
Seminoma			
Analog only	62/101	1.0	0.7–1.4
Digital only	55/71	1.5	0.96–2.2
Cordless only	50/88	1.0	0.7–1.4
Analog + Digital	30/40	1.3	0.8–2.2
Analog + cordless	41/51	1.5	0.9–2.3
Digital + cordless	22/45	1.0	0.5–1.7
Analog + Digital + cordless	9/19	0.9	0.4–2.1
Total, any combination	243/358	1.2	0.9–1.5
Non-seminoma			
Analog only	15/101	0.4	0.2–0.7
Digital only	33/71	0.9	0.5–1.5
Cordless only	35/88	1.1	0.7–1.7
Analog + Digital	22/40	1.4	0.8–2.5
Analog + cordless	24/51	1.1	0.6–1.9
Digital + cordless	22/45	1.0	0.6–1.8
Analog + Digital + cordless	11/19	1.4	0.6–3.3
Total, any combination	129/358	0.8	0.6–1.1

association was found for different location or according to laterality of the phone and side of testicular cancer. Most ORs were close to unity. As in Table 4 subjects always using external antenna in a car were included in the calculations.

Cryptorchidism was associated both with seminoma (OR = 4.2, 95 CI = 2.7–6.5; 76 cases, 32 controls) and non-seminoma (OR = 3.3, CI = 2.0–5.6; 38 cases, 32 controls). No interaction was found between the use of cellular and cordless phones and cryptorchidism (data not shown).

Discussion

This was a population based case–control study on testicular cancer. Cases were identified from the Swedish Cancer Register. The reporting of new cases to the register is compulsory and it has a high inclusion of new cases as both a histopathological and a clinical report is sent to the register. This study included prevalent cases during the time period 1993–1997 and only 37 (3%) of the cases had died, as the prognosis of testicular cancer is good. In total, 92% of the cases in the register were included in the study, thus it is unlikely that any selection bias of importance occurred. The response rate was high both for cases and controls, which is of importance to minimize bias in exposure reporting.

Assessment of use of cellular and cordless phones was one part in this study that mainly concerned occupational exposures. The results regarding contact with PVC have already been reported (Hardell *et al.*, 2004b; Westberg *et al.*, 2005). We used the same questions for wireless

Table 4 Number of exposed cases (Ca) with testicular cancer and controls (Co), odds ratio (OR) and 95% confidence interval (CI) for cellular telephones during standby. Unconditional logistic regression analysis adjusted for age, year of diagnosis and cryptorchidism was used. In the dose–response calculations the median number of cumulative use in hours among controls in the total material was used as the cut-off

	>1–5 year latency		>5–10 year latency		>10 year latency		Total, >1 year latency	
	Ca/Co	OR (CI)	Ca/Co	OR (CI)	Ca/Co	OR (CI)	Ca/Co	OR (CI)
Total (n = 888, 476 unexposed)								
Mobile phone, standby[a]	202/202	1.0 (0.8–1.3)	105/85	1.3 (0.9–1.8)	34/21	1.6 (0.9–2.9)	341/308	1.1 (0.9–1.4)
≤17520 h[b]	144/146	1.0 (0.7–1.3)	23/15	1.7 (0.9–3.4)	5/2	2.8 (0.5–15)	172/163	1.1 (0.8–1.4)
>17520 h[b]	46/40	1.1 (0.7–1.8)	77/65	1.2 (0.8–1.7)	28/19	1.4 (0.8–2.6)	151/124	1.2 (0.9–1.6)
Seminoma (n = 542, 277 unexposed)								
Mobile phone, standby[a]	131/202	1.2 (0.9–1.6)	69/85	1.4 (0.99–2.0)	23/21	1.7 (0.9–3.1)	223/308	1.3 (1.03–1.7)
≤17520 h[b]	96/146	1.2 (0.9–1.7)	17/15	1.9 (0.9–4.0)	3/2	1.8 (0.3–11)	116/163	1.3 (0.99–1.8)
>17520 h[b]	29/40	1.4 (0.8–2.4)	48/65	1.3 (0.9–2.0)	19/19	1.6 (0.8–3.1)	96/124	1.4 (1.01–1.9)
Non-seminoma (n = 346, 199 unexposed)								
Mobile phone, standby[a]	71/202	0.8 (0.6–1.1)	36/85	1.2 (0.8–1.9)	11/21	1.8 (0.8–4.0)	118/308	0.9 (0.7–1.3)
≤17520 h[b]	48/146	0.7 (0.5–1.1)	6/15	1.8 (0.6–4.9)	2/2	6.2 (0.8–50)	56/163	0.8 (0.6–1.2)
>17520 h[b]	17/40	0.9 (0.5–1.7)	29/65	1.2 (0.7–2.0)	9/19	1.6 (0.7–3.8)	55/124	1.1 (0.7–1.6)

[a]Time (years) was missing for one control, hence excluded from the analysis.
[b]Number of hours missing for 18 cases and 21 controls.

Table 5 Number of exposed cases (Ca) with testicular cancer and controls (Co), odds ratio (OR) and 95% confidence interval (CI) for use of cellular telephones for tumour location in relation to the location of the mobile phone using >1 year latency period. Ipsilateral = same side for cancer and phone, contralateral = opposite side. Unconditional logistic regression analysis adjusted for age, year of diagnosis and cryptorchidism was used. Note that more than one phone location was reported by some subjects

Locality/type of telephone	All Ca/Co OR (CI)	Ipsilateral Ca/Co OR (CI)	Contralateral Ca/Co OR (CI)
Total			
Pocket on trouser-leg	34/52	20/24	14/27
	0.6 (0.4–0.99)	0.7 (0.4–1.4)	0.5 (0.2–0.9)
Trousers pocket	56/47	42/24	27/27
	1.1 (0.7–1.7)	1.4 (0.8–2.5)	0.9 (0.5–1.6)
Hip-pocket	16/23	8/10	8/14
	0.7 (0.4–1.4)	0.7 (0.3–1.8)	0.6 (0.2–1.4)
Waist-belt pocket	100/87	56/35	42/41
	1.1 (0.8–1.6)	1.5 (0.9–2.3)	0.9 (0.6–1.5)
Breast-pocket	123/104	70/54	66/53
	1.2 (0.9–1.6)	1.1 (0.8–1.7)	1.2 (0.8–1.7)
Seminoma			
Pocket on trouser-leg	20/52	11/24	9/27
	0.7 (0.4–1.3)	0.9 (0.4–1.9)	0.6 (0.3–1.3)
Trousers pocket	33/47	25/24	14/27
	1.3 (0.8–2.2)	1.8 (0.97–3.4)	1.0 (0.5–2.0)
Hip-pocket	11/23	7/10	4/14
	0.9 (0.4–1.9)	1.2 (0.4–3.2)	0.5 (0.2–1.7)
Waist-belt pocket	65/87	32/35	31/41
	1.4 (0.97–2.0)	1.5 (0.9–2.6)	1.3 (0.8–2.2)
Breast-pocket	78/104	45/54	39/53
	1.4 (0.9996–2.0)	1.4 (0.9–2.1)	1.3 (0.8–2.1)
Non-seminoma			
Pocket on trouser-leg	14/52	9/24	5/27
	0.5 (0.3–0.99)	0.6 (0.3–1.4)	0.4 (0.1–1.03)
Trousers pocket	23/47	17/24	13/27
	1.1 (0.6–1.9)	1.3 (0.6–2.5)	1.0 (0.5–2.0)
Hip-pocket	5/23	1/10	4/14
	0.6 (0.2–1.8)	0.3 (0.03–2.2)	0.7 (0.2–2.4)
Waist-belt pocket	35/87	24/35	11/41
	1.0 (0.6–1.6)	1.7 (0.9–3.0)	0.5 (0.3–1.1)
Breast-pocket	45/104	25/54	27/53
	1.0 (0.6–1.5)	1.0 (0.6–1.6)	1.1 (0.7–1.9)

communication as in our studies on other tumour types during that time period (Hardell *et al.*, 2004c, 2005, 2006b,c). In this study we also added questions on the position of the mobile phone during standby. The exposure to microwaves during standby is very low, at most a few signals per hour for location of the closest base station. No case or control had always used a hands-free, and therefore the mobile phone was not close to the testis during phone calls. In fact, only 11 cases and eight controls had at some time used a hands-free device.

It might be difficult to get reliable answers on the question about mean minutes of daily use of mobile or cordless phones. Type of mobile phone, analog or digital, is easier to remember due to different prefix – 010 for analog phone and 07 for digital phone. It is almost impossible to get information about the model of the phone and the manufacturer. However, any recall bias should be similar for cases and controls as testicular cancer has not been associated with the use of mobile or cordless phones in the population.

The exposures were assessed and coded in a blinded way as to case or control status to avoid observational bias. If necessary, supplementary phone calls were made to the study subjects to clarify exposure details in the questionnaires, without knowledge as to whether it was a case or a control.

In the analysis we adjusted for age, year of diagnosis and cryptorchidism as cryptorchidism is an established

risk factor for testicular cancer. As the mean age for cases with seminoma was 10 years higher than for non-seminoma cases and the controls were age matched in 5-year groups, it was necessary to adjust for age in the unconditional logistic regression analysis. In the analysis adjustment was also made for year of diagnosis as the use of both cellular and cordless phones has increased over the years.

The main result of this study was no association between the use of cellular or cordless telephones and testicular cancer. This finding is in accordance with the hypothesis that the fetal period is the most important period regarding the risk of testicular cancer. We found some significant associations that might be explained by the large number of analyses as there seemed to be no biological relevance of the findings.

It should be noted that few subjects had used such phones with long enough latency periods, and therefore long-term health risks cannot be evaluated. In fact, only 14 cases (13 with seminoma and one with non-seminoma) and nine controls had used analog phones with a latency period >10 years and no subject had used a digital or cordless phone with that latency period. For seminoma significantly increased OR were calculated in the lowest exposure group with >1 year latency period for all phone types in question. However, there was no dose–response effect and no significant trend for increasing OR with increasing latency period. In fact, in some of the calculations, OR decreased with latency period with a significant trend. As one would expect, cryptorchidism was associated with an increased risk for both seminoma and non-seminoma. The use of cellular or cordless phones did not interact with cryptorchidism as a risk factor.

Regarding seminoma somewhat increased ORs were found for mobile phones during standby. There was no dose–response effect and these results may only reflect the use of a mobile phone (see Table 2). Furthermore, when analysing the location of the mobile phone during standby time no association was found with testicular cancer. Keeping the phone in a pocket close to the testis did not increase the risk and there was no association with laterality of the phone and cancer. The subjects did not regularly keep the phone in a pocket during phone calls as no person had always used hands-free devices. Exposure to microwaves, although very low, would only occur during a signal from the phone to the base station for position during standby.

In summary, this study did not find evidence that the use of cellular or cordless phones increases the risk of testicular cancer, although long-term health effects cannot be ruled out. However, our results in other studies of an association with brain tumours are strengthened as these studies were performed with overlapping time for interview with similar study methods.

Acknowledgements

Grant sponsors include the Swedish Council for Work Life Research, Örebro Cancer Fund, Nyckelfonden, Cancer-och Allergifonden and Cancerhjälpen. The authors thank Iréne Larsson and Mats Eriksson for assistance in data collection.

References

Aitken, R. J., Bennetts, L. E., Sawyer, D., Wiklendt, A. M. & King, B. V. (2005) Impact of radio frequency electromagnetic radiation on DNA integrity in he male germline. *International Journal of Andrology* 28, 171–179.

Almstrup, K., Fernández, M. F., Petersen, J. H., Olea, N., Skakkebaek, N. E. & Leffers, H. (2002) Dual effects of phytoestrogens result in U-shaped dose–response curves. *Environmental Health Perspectives* 110, 743–748.

Bray, F., Richiardi, L., Ekbom, A., Pukkala, E., Cuninkova, M. & Moller, H. (2006) Trends in testicular cancer incidence and mortality in 22 European countries: continuing increases in incidence and declines in mortality. *International Journal of Cancer* 118, 3099–3111.

Fejes, I., Závaczki, Z., Szöllősi, J., Koloszár, S., Daru, J., Kovács, L. *et al.* (2005) Is there a relationship between cell phone use and semen quality? *Archives of Andrology* 51, 385–393.

Hardell, L., Holmberg, B., Malker, H. & Paulsson, L. E. (1995) Exposure to electromagnetic fields and the risk of malignant diseases – an evaluation of epidemiological and experimental findings. *European Journal of Cancer Prevention* 4 (Suppl. 1), 3–107.

Hardell, L., Ohlson, C. G. & Fredrikson, M. (1997) Occupational exposure to polyvinyl chloride as a risk factor for testicular cancer evaluated in a case–control study. *International Journal of Cancer* 73, 828–830.

Hardell, L., van Bavel, B., Lindström, G., Carlberg, M., Dreifaldt, A. C., Wijkström, H. *et al.* (2003) Increased concentrations of polychlorinated biphenyls, hexachlorobenzene and chlordanes in mothers to men with testicular cancer. *Environmental Health Perspectives* 111, 930–934.

Hardell, L., van Bavel, B., Lindström, G., Carlberg, M., Eriksson, M., Dreifaldt, A. C. *et al.* (2004a) Concentrations of polychlorinated biphenyls in blood and the risk for testicular cancer. *International Journal of Andrology* 27, 282–290.

Hardell, L., Malmqvist, N., Ohlson, C. G., Westberg, H. & Eriksson, M. (2004b) Testicular cancer and occupational exposure to polyvinyl chloride plastics: a case–control study. *International Journal of Cancer* 109, 425–429.

Hardell, L., Hallquist, A., Hansson Mild, K., Carlberg, M., Gertzén, H., Schildt, E. B. *et al.* (2004c) No association between

the use of cellular or cordless telephones and salivary gland tumours. *Occupational and Environmental Medicine* 61, 675–679.

Hardell, L., Eriksson, M., Carlberg, M., Sundström, C. & Hansson Mild, K. (2005) Use of cellular and cordless telephones and the risk for non-Hodgkin's lymphoma. *International Archives of Occupational Environmental Health* 78, 625–632.

Hardell, L., van Bavel, B., Lindström, G., Eriksson, M. & Carlberg, M. (2006a) In utero exposure to persistent organic pollutants in relation to testicular cancer risk. *International Journal of Andrology* 29, 228–234.

Hardell, L., Carlberg, M. & Hansson Mild, K. (2006b) Pooled analysis of two case–control studies on the use of cellular and cordless telephones and the risk for benign brain tumours diagnosed during 1997–2003. *International Journal of Oncology* 28, 509–518.

Hardell, L., Carlberg, M. & Hansson Mild, K. (2006c) Pooled analysis of two case–control studies on use of cellular and cordless telephones and the risk for malignant brain tumours diagnosed in 1997–2003. *International Archives of Occupational Environmental Health* 79, 630–639.

Henderson, B. E., Benton, B., Jing, J., Yu, M. C. & Pike, M. C. (1979) Risk factors for cancer of testis in young men. *International Journal of Cancer* 23, 598–602.

National Board of Health and Welfare (2006) Centre for Epidemiology. Cancer Incidence in Sweden 2004. Health and Diseases 2005:9. http://www.socialstyrelsen.se/Statistik/statistik_amne/Cancer [accessed 13 June 2006].

Ohlson, C. G. & Hardell, L. (2000) Testicular cancer and occupational exposures with a focus on xenoestrogens in polyvinyl chloride plastics. *Chemosphere* 40, 1277–1282.

Schottenfeldt, D., Warshauer, M. E., Sherlock, S., Zauber, A. G., Leder, M. & Payne, R. (1980) The epidemiology of testicular cancer in young adults. *American Journal of Epidemiology* 112, 232–246.

Skakkebæk, N. E., Rajpert-De Meyts, E. & Main, K. M. (2001) Testicular dysgenesis syndrome: an increasingly common developmental disorder with environmental aspects. *Human Reproduction* 16, 972–978.

Toppari, J., Skakkebaek, N. E. & Larsen, J. C. (eds) (1995) Male Reproductive Health and Environmental Chemicals with Estrogenic Effects. Miljöprojekt 290. Danish Environmental Protection Agency, Copenhagen, Denmark.

Westberg, H., Hardell, L., Malmqvist, N., Ohlson, C. G. & Axelson, O. (2005) On the use of different measures of exposure – experiences from a case–control study on testicular cancer and PVC exposure. *Journal of Occupational and Environmental Hygiene* 2, 351–356.