

# FOCUS ON TOMORROW

RESEARCH FUNDED BY WORKSAFEBC

## A Retrospective Cohort Study of Mortality and Cancer Incidence among Registered Nurses in British Columbia

June 2006

Principal Investigator/Applicant  
Dr. Helen Ward

RS2000/01-015

**WORK SAFE BC**

WORKING TO MAKE A DIFFERENCE

# **A Retrospective Cohort Study of Mortality and Cancer Incidence among Registered Nurses in British Columbia**

## **Revised Report to the Research Secretariat of WorkSafeBC**

**June, 2006**

### **Investigators:**

Helen D. Ward, PhD<sup>1</sup>

Kay Teschke, PhD<sup>1</sup>

Pamela A. Ratner, PhD, RN<sup>1</sup>

Nhu Le, PhD<sup>1,2</sup>

John Spinelli, PhD<sup>1,2</sup>

Richard Gallagher, MA<sup>1,2</sup>

### **Research staff:**

Yat Chow, MSc<sup>1</sup>

Joanna Chung, BSc<sup>3</sup>

Danhong Shu, BSc<sup>1,2</sup>

Maria Lorenzi, MSc<sup>2</sup>

Olha Demchenko, MD<sup>3</sup>

<sup>1</sup> University of British Columbia

<sup>2</sup> Cancer Control Research Program, British Columbia Cancer Agency

<sup>3</sup> SFU Cooperative Education (employed by Department of Medicine, UBC)

## TABLE OF CONTENTS

1. EXECUTIVE SUMMARY	4
2. RESEARCH PROBLEM	8
3. BACKGROUND	8
3.1 Mortality and Cancer Incidence among Nurses	8
3.2 Carcinogens in the Nursing Environment	10
4. METHODS	12
4.1 Overview	12
4.2 RN Cohort Identification and Work History	12
4.3 Data Preparation	13
4.4 National Mortality and Cancer Data Files	14
4.5 Linkage with Data Files	15
4.6 Linkage to the National Dose Registry	16
4.7 Exposure Assessment	17
4.8 Statistical Analysis	21
4.9 Ethics	23
5. RESEARCH FINDINGS	24
5.1 Description of the RN Cohort	24
5.2 Causes of death - Standardized Mortality Ratios	27
5.3 Cancer - Standardized Incidence Ratios	32
5.4 Cancer Incidence for Female RNs According to Years Worked as a Nurse	35
5.5 Mortality and Cancer Incidence of Female RNs by Field of Employment	37
5.6 Exposure Ascertainment for the Relationship of Specific Exposures with Cancer Incidence	41
6. DISCUSSION	42
7. POLICY AND PREVENTION	49
8. DISSEMINATION AND KNOWLEDGE TRANSFER	50
9. ACKNOWLEDGEMENTS	52
10. REFERENCES	54

## TABLES

Table 1. Distribution of the BC RN Cohort According to Year of Birth .....	24
Table 2. Distribution of the BC RN Cohort According to Number of Years Registered as a Nurse in BC .....	24
Table 3. Distribution of the BC RN Cohort According to Year of Initial Registration in BC .....	25
Table 4. Description of the BC RN Cohort by Gender and Year .....	26
Table 5. Cancer Mortality (Standardized Mortality Ratios) for Female RNs in BC in Comparison to the BC General Population .....	28
Table 6. Non-cancer Mortality (Standardized Mortality Ratios) for Female RNs in BC in Comparison to the BC General Population .....	30
Table 7. Causes of Mortality (SMRs) for Male RNs in BC in Comparison to the BC General Population .....	32
Table 8. Cancer Incidence (Standardized Incidence Ratios) for Female RNs in BC in Comparison to the BC General Population .....	33
Table 9. Cancer Incidence (Standardized Incidence Ratios) for Male RNs in BC in Comparison to the BC General Population .....	35
Table 10. Relative Risks for Cancer Incidence Among Female RNs According to Years Worked as a Nurse.....	36
Table 11. Relative Risks Among Female RNs According to Employment in Maternal Newborn or Paediatrics (1974-2000) .....	37
Table 12. Relative Risks Among Female RNs According to Employment in Medical/Surgical Specialties (1979-2000) .....	39
Table 13. Relative Risks Among Female RNs According to Employment in Gerontology (1974-2000) .....	40
Table 14. Relative Risks Among Female RNs According to Employment in Mental Health (1974-2000) .....	41

Table 15. Relative Risks for Cancer Incidence According to Potential Exposure to Ionizing Radiation (based on survey).....	42
--	----

## **APPENDICES**

APPENDIX I: JOB TITLE INFORMATION.....	59
APPENDIX II: EXPOSURE ALGORITHMS.....	61
APPENDIX III: ICD 9 CODES.....	62
APPENDIX IV: DOSIMETRY RESULTS.....	65

## **1. EXECUTIVE SUMMARY**

### Research Problem

In the course of their work, nurses may be exposed to a wide range of physical, chemical and biological hazards, including such known carcinogens as antineoplastic agents and ionizing radiation. We undertook a retrospective cohort study of registered nurses (RNs) who were members of the Registered Nurses Association of British Columbia (the regulatory body responsible for registering nurses) between 1974 and 2000. The objectives of the study were to determine whether RNs had a greater risk of cancer incidence or mortality from all causes in comparison to the BC population; and to evaluate whether there was a greater risk of cancer associated with working in a particular job category or with the extent of exposure estimated for specific agents.

### Methods

RNs registered for at least one year with the RNABC between 1974 and 2000 comprised the cohort. To assist with exposure assessment, a telephone survey of experienced nurses at all 113 hospitals and health care centres in BC was undertaken. A questionnaire was developed to ascertain whether specific agents (antineoplastic drugs, anaesthetic gases, or ionizing radiation) were used during a given year between 1974 and 2000 within specific hospital departments. As well, information on the probability of exposure by employment status and on the types of exposure control measures used was obtained.

Cohort records were linked to the Canadian Mortality Data Base from 1974 to 2000, and to the National Cancer Registry from 1974 to 1999. Alive follow-up was also conducted by Statistics Canada using internal linkages. To obtain quantitative ionizing radiation exposure information, further linkage was undertaken by Statistics Canada using Health Canada's National Dose Registry files. Standardized mortality (SMR) and incidence ratios (SIR) were calculated to compare cancer mortality and incidence rates for the RN cohort to those of the BC population. Internal comparisons were based on cumulative years of employment in a job category (never, less than 5 years or greater or equal to 5 years) and whether there was minimal or likely exposure to a specific agent. Poisson regression analysis of non-cancer causes of death and cancer incidence was undertaken with

adjustment for age and calendar year and lagged by 10 years to take into account typical latency intervals between exposure and disease.

### Research Findings

There were 58,125 RNs in the cohort, consisting of 1,912 males and 56,213 females (96.7%). Almost all (98%) hospitals and health care centres participated in the survey for the exposure assessment component of the study. Of the 58,125 RNs in the cohort, 3,470 nurses (6.0%) were found to have dosimetry data in the National Dose Registry, with a total of 16,246 person-years of measurements.

The SMR for all causes of mortality for the cohort of female RNs was 0.61 (95% CI, 0.58-0.64). There were 2,157 deaths in total. The most common cancers causing death of females in the cohort were breast cancer (274 deaths) and lung cancer mortality (169 deaths), but the respective SMRs (0.87 and 0.56) were based on significantly lower rates compared to the general BC female population. Significantly lower SMRs (around 0.5) were found for cardiovascular-related causes and chronic obstructive pulmonary disease.

For the relatively small percentage of male RNs, the overall SMR was 1.00 (95% CI 0.79 - 1.24; 81 deaths). The only cause of death that was significantly elevated was “other infective and parasitic diseases” (SMR 5.86, 95% CI 3.79 - 8.65; 25 deaths). The risk of death from all cancers was low (SMR 0.71, 95% CI 0.39 - 1.19; 14 deaths). For cancer incidence, the overall SIR for cancer was 1.06 (95% CI 0.78-1.41), based on only 46 cases. There were no statistically significant elevated incidence rates for specific cancers in comparison to the male population in BC.

For female RNs, the overall SIR for cancer incidence was 0.91 (95% CI 0.88-0.94), based on 3,062 observed cases. The only statistically significant elevation in risk of cancer in comparison to the BC female population was for malignant melanoma (SIR 1.27, 95% CI 1.10-1.46; 206 cases). Cancers of the breast (1.05, 95% CI 0.99-1.11; 1,286 cases) and large intestine (SIR 1.13, 95% CI 0.99-1.28; 238 cases) were elevated but just failed to reach statistical significance. For other common cancers such as uterine including cervical cancer (306 cases) and ovarian cancer (150 cases), the SIRs were 0.84 and 0.94, respectively. There was one-half the risk of lung cancer (216 cases); the SIR was significantly lower at 0.59 (95% CI 0.51 - 0.67). Increasing years of work as a RN were associated with increased risks of breast cancer, lung cancer, malignant melanoma and rectal cancer.

Because internal comparisons based on cumulative years of work in a particular job category were limited to years since 1974 the results should be interpreted cautiously. Years spent in a specific job category prior to 1974 or outside of BC could not be accounted for, thus each of the exposure categories may be misclassified to some extent. Notwithstanding this limitation, several increased risks for mortality and cancer were apparent according to job category and estimated exposure, and based on analyses lagged 10 years.

RNs who had worked under 5 years in maternal newborn or paediatric nursing departments during 1974-2000 had significantly increased risks for death from chronic obstructive pulmonary disease (RR 2.93; 8 deaths) and significantly increased incidence of leukaemia (RR 2.16; 9 cases) and oesophageal cancer (RR 4.20; 4 cases). Working more than 5 years was associated with a significantly elevated risk for cancer of the pancreas (RR 3.92; 4 cases). Having ever worked in maternal newborn or paediatric nursing also was associated with an increased risk of mortality from blood diseases and gall bladder cancer, based on 3 and 5 exposed cases respectively.

There was an elevated risk of lung cancer (RR 2.57; 14 cases) associated with working under 5 years in medical/surgical specialty nursing departments (including operating room, emergency care and other critical care units), as well as a higher risk of chronic obstructive pulmonary disease (RR 2.91; 5 cases). The risks of death due to blood diseases, diseases of the veins and lymphatics and of other endocrine metabolic diseases were elevated, but there were only 3 to 4 cases each of RNs ever exposed who developed those diseases.

Nursing in gerontology for less than 5 years was associated with a significantly higher risk of death from rheumatic heart disease (RR 4.01; 6 cases); those working for at least 5 years in gerontology had a higher risk of diabetes (RR 6.51; 3 cases). A high risk of other endocrine cancer (including thymus, adrenal and parathyroid glands) was consistently found for all exposure groups.

Although employment in the mental health field was not associated with any elevated risk of cancer, the risk of dying from acute myocardial infarction was over twice as high for those working under 5 years (RR 2.56; 14 cases), as was the risk of suicide (RR 3.03; 5 cases). Ever being employed in that field during the period 1974-2000 was associated with having chronic obstructive lung disease (RR 2.48; 6 cases).

Because of the short time interval (1990-2000) for which pertinent field of employment information was available concerning exposure to anaesthetic gases, there were insufficient numbers of cases to allow for further analysis. Estimates of the potential for exposure to antineoplastic drugs during the period of 1974-2000 were not related to cancer incidence. However, ever having employment in a cancer centre or oncology was associated with an increased risk of breast cancer (RR 1.83; 12 cases).

RNs that ever had exposure to sources of ionizing radiation had a significantly increased risk of breast cancer (RR 1.21; 140 cases). There were elevated risks of lymphatic leukaemia for those classified as having minimal exposure to ionizing radiation (RR 9.70; 4 cases) as well as likely exposure (RR 4.86; 3 cases). For the subset of BC RNs for whom ionizing radiation dosimetry measurements were available, there was an elevated risk of bladder cancer (including in-situ) but it was based on 2 cases and was limited to those who wore dosimetry badges (all of whom had measurements lower than the limit of detection).

### Discussion

A healthy worker effect was evidenced by the relatively low risks of specific causes of mortality among the cohort of RNs. The association between years employed as an RN with specific cancers (breast, lung, large intestine and malignant melanoma) suggests that some aspects of nursing may be hazardous. Internal comparisons showed some intriguing excess risks related to work in specific job categories. However, the risk estimates were usually based on a small number of cancer cases or deaths and there is the possibility of findings occurring by chance alone because of the multiple comparisons.

Further investigations are warranted not only to confirm these study findings but also to examine the effects of such hazards as rotating shift and night work and to evaluate other adverse health outcomes, such as adverse reproductive outcomes.

## **2. RESEARCH PROBLEM**

There are at least 135 agents used in the health care industry that are associated with an elevated risk of cancer or reproductive effects (*Omenn et al, 1984*). There are numerous case reports describing individual occupational health hazards in the nursing and medical professions, but epidemiological evidence is relatively scarce. There have been very few large occupational cohort studies of nurses, or other health care workers. The Harvard Nurses' Health Study, a longitudinal prospective study of 121,700 female registered nurses followed since 1976, has contributed significantly to our understanding of the aetiology and prevention of major illnesses among women (*Colditz et al, 1997*). Yet, very few of the more than 100 publications arising from this study have addressed the specific issue of occupational health risks for nurses.

There remain several unanswered questions concerning occupational health risks for nurses. The objectives of the current study were to:

1. determine if there was an increased risk in registered nurses of specific causes of mortality and incidence of cancers in comparison to the BC population;
2. evaluate whether employment in a particular job category and duration of employment was associated with an increased risk of cancer incidence or specific causes of mortality;
3. assess if potential exposure to specific agents or measurement of ionizing radiation were associated with the incidence of specific cancers.

## **3. BACKGROUND**

### **3.1 Mortality and Cancer Incidence among Nurses**

Since the 1980s there have been several publications concerning the mortality of nurses, presenting either proportionate mortality rates (PMRs) or mortality odds ratios (MORs), where deaths from a specific cause were compared to deaths from all other causes. A PMR study was performed on British Columbia occupational data from 1950-1984 (*Gallagher et al, 1989*). Significant PMRs were found for female nurses (n=2,806; age range 20 years and older) as shown in the table below:

<b>Cause of Death</b>	<b>Deaths (n)</b>	<b>PMR</b>	<b>95% Confidence Interval</b>
All cancers	744	114	105 - 123
Breast	170	120	103 - 140
Ovarian	75	156	124 - 195
Leukaemia	32	144	102 - 204
Arteriosclerosis	685	91	84 - 99
Motor Vehicle Accident	103	158	129 - 192
Suicide	75	159	126 - 200
Cirrhosis of liver	28	62	41 - 90

Additional analyses showed that the PMRs for breast and ovarian cancers were lower once homemakers were excluded from the comparison group (*Threlfall et al, 1985*). It was suggested that using homemakers in the comparison group introduced reproductive factors, including higher parity and earlier maternal age at first birth, which are known to be associated with a reduced risk of breast and ovarian cancer.

An American PMR study found elevated risks for breast cancer (PMR 125;  $p < 0.01$ ) and cancer of the nervous system (PMR 161;  $p < 0.05$ ) for registered nurses when compared to all female workers (*Katz, 1983*). However, when the comparison group was limited to female professional workers, the risks of cancer were diminished. A recent death certificate study of health care workers in the U.S. found that white and black RNs have significantly increased risks of mortality with MORs ranging from 1.2 to 1.3 for several specific cancers, including cancer of the breast, ovary, brain, liver and of myeloid leukaemia (*Petralia et al, 1999a*).

The determinant of cancer incidence was evaluated in a case-control study of Washington state nurses. An elevated, but not statistically significant risk of 1.4 (95% CI 0.8-2.5) was found for all breast cancers for nurses employed for at least 5 years (*Habel et al, 1995*). Menopausal status appears to be an important consideration. A recent case control study of teachers and nurses found no association between ever having been a nurse or duration of nursing with premenopausal cancer (*Petralia et al, 1999b*). On the other hand, *Band and colleagues (2000)*, at the BC Cancer Agency, in a case-control study of

incident breast cancer cases, found that women who had ever been a nurse (registered, graduate, or in training) had a significantly increased risk for post-menopausal breast cancer (OR 1.48, 95% CI 1.03-2.12).

In summary, findings from the literature suggest that nurses may have higher risks of breast and ovarian cancers, as well as leukaemia and malignant melanoma. The findings are inconsistent however, and deserve more thorough study of the potential occupational risk factors for cancer in nurses.

### **3.2 Carcinogens in the Nursing Environment**

In the nursing environment there are several known and suspected carcinogens, including sterilizing agents, viruses, antineoplastic drugs, anaesthetics and associated waste gases, and electromagnetic fields, particularly ionizing radiation. Rotating shifts and night work, which are common to the health professions, have been linked to breast cancer, possibly related to the disruption of melatonin (*Davis et al, 2001; Hansen, 2001; Schernhammer et al, 2001*). Separate reports submitted to the Workers' Compensation Board of BC (*Ward et al, 2005*) concern potential exposures and health effects of antineoplastic agents, ionizing radiation and anaesthetic gases, which are summarized below.

#### **3.2.1 Antineoplastic Agents**

Antineoplastic drugs have been used in the treatment of malignant diseases for more than 40 years and there are more than 50 types commercially available for the treatment of cancer (*Baker et al, 1996*). Health care workers may be exposed through inhalation of the aerosolized drug product and by direct skin contact (*Labuhn et al, 1998*). Although the intensities of exposure are much less than those incurred by patients receiving the treatment, occupational exposures may be of longer cumulative duration and biomarkers of effect, such as an increased frequency of sister chromatid exchanges, have been detected (*Norppa et al, 1980*). A recent review of methods used to monitor occupational exposure to cytostatic drugs concluded that despite the introduction of safety guidelines and protective measures, health care workers can still be exposed to these toxic drugs (*Sessink et al, 1999*).

### 3.2.2 Anaesthetic Gases

Many of the widely used anaesthetic agents, such as nitrous oxide, cyclopropane, methoxyflurane, halothane and ether have been found to be mutagenic in laboratory animal studies (*Infante et al, 1985*) and may interfere with the immune system and affect susceptibility to infections and tumours (*Goto et al, 2000; Jaloszynski et al, 1999; Peric et al, 1991; Bargellini et al, 2001*). Desflurane, isoflurane, nitrous oxide, halothane and sevoflurane have been detected in operating and post-anaesthesia recovery rooms (PARRs) based on air sampling, urine testing and monitoring the exhaled gas of patients and staff (*Accorsi et al, 2001; Hobbhahn et al, 1998; Hoerauf et al, 1996; Hoerauf et al, 1997; Imberti et al, 1995; Prado et al, 1997; Sessler et al, 1998; Nikki et al, 1972*).

A review of studies of operating room (OR) personnel, completed over 20 years ago, concluded that there were increased risks for female health care workers employed in ORs, of total malignancies (RR 1.4) and cervical cancer (RR 2.8) (*Buring et al, 1985*). With the use of improved scavenging techniques and instruments, exposure to waste gases should be minimized, although further study of the health effects of exposure to anaesthetic gas exposure is still needed.

### 3.2.3 Ionizing Radiation

Sources of ionizing radiation for health care workers include portable x-ray machines (used in ORs, post-anaesthetic recovery rooms, emergency rooms, intensive care units, and other units when patients are too ill, unstable or immunocompromised to be transported to X-ray departments) and emission of gamma rays by patients being treated with radionuclides or implants (*Sass-Kortsak et al, 1992*). Much of the epidemiological evidence on radiation damage to humans is attributed to populations where high levels of exposure may have occurred, such as in the event of a nuclear explosion. For instance, studies on atomic bomb survivors have shown increased risks of leukaemia and most solid cancers (*Ron, 1998*). Nuclear power workers were found to have a mean cumulative whole body radiation dose 100 times that of dental workers (28.50 mSv versus 0.31 mSv above background) (*Ashmore et al, 1998*).

According to the National Dose Registry (Section 4.4.3), the average annual dosage for Canadian nurses was 0.10 mSv in 2002 (*Sont, 2003*). The current national permissible limit for the effective whole body dose is much higher at 50 mSv per year. The question remains

as to whether nurses are at risk for cancer as a result of unintentional exposure to ionizing radiation.

## **4. METHODS**

### **4.1 Overview**

The retrospective cohort study was carried out using the following basic steps:

- A cohort file was created of RNs registered for at least one year with the Registered Nurses Association of BC (RNABC), the professional regulatory body, between 1974 and 2000 (now the College of Registered Nurses of BC);
- Upon standardization of the work history job categories, a survey of BC hospitals and health care centres was conducted to determine the probability of exposure to antineoplastic agents, anaesthetic gases and ionizing radiation;
- Statistics Canada conducted probabilistic data linkage to the Canadian Mortality Database Probabilistic with alive follow-up to December 31, 2000;
- Statistics Canada also linked the cohort file to the National Cancer Database;
- Quantitative exposure to ionizing radiation for a subset of the cohort was facilitated through linkage of the cohort file by Statistics Canada to the National Dose Registry;
- Data analysis was based on standardized risk estimates and Poisson regression techniques.

### **4.2 RN Cohort Identification and Work History**

The RNABC records were the only source of data for identifying the cohort. Membership with the association has been virtually complete for practising registered nurses since 1916 (*RNABC, 1986*). Information was obtained annually from each nurse for membership renewal purposes. RNABC registrations have been computerized since 1974. The data are kept up-to-date by the RNABC and maintained through the Health Human Resources Unit of the Centre for Health Services and Policy Research at the University of British Columbia. Records were amalgamated by year for each nurse. An indicator variable was added to the file to show changes in data fields with numbers representing each year from 1974 to 2000.

The cohort consisted of all nurses registered with the RNABC for at least one continuous year (with at least one annual registration renewal form completed after initial registration) since 1974. A computerized file of the nominal roll was sent to Statistics Canada to prepare for linkage. The elements available for linkage for each nurse were: full name, address, postal code, sex, birth date, social insurance number, marital status, maiden name and the last year registered in British Columbia. There was no missing information on full names, sex, birth year and last known address. The day of birth was missing for 29.1%. Only 6.2% had missing social insurance numbers; for 72.6%, maiden names were available for linkage.

Annual registrations contained variables pertinent to job descriptions (Appendix I a). The structure of the form has been consistent since 1974, however, the number of categories used has increased somewhat. For instance, there were 13 categories for the field of employment (primary area of responsibility) in 1974, increasing to 27 categories in 2000. An example is the evolution of the categories involving the medical/surgical specialties from 1974-2000 (Appendix I b).

### **4.3 Data Preparation**

Statistics Canada returned a file identifying inconsistent sex fields after linkage. After first reconciling 228 illogical records based on names, the remaining 30 subjects were reclassified using the most recent renewal form from their original paper records at the RNABC offices. Invalid SIN numbers (n=238) were also identified by Statistics Canada. Records of subjects missing both a complete birth date and a SIN number or incorrect SIN number were checked against the original paper copies stored at the RNABC.

#### **4.3.1 Work History**

There were inconsistencies in the work history file due to various changes in the RNABC registration form and errors made during registration or data entry. For example, from 1974 – 1978 full-time/part-time status information was not available; instead, full time status was classified as working 35 or more hours per week. All analysis was based on the primary employer information. Data were available for a second employer from 1988 and a third employer since 1996. Where information was not available for the primary employer (n=262), data from the second employer was used. Registration date and final

year worked (2000 for current workers) were used to calculate years worked as an RN in BC, taking into account a weighting of 0.5 for part-time work during 1974-2000.

No reference guide was available for the older coding system used for the employer data (e.g., hospital name) prior to 1977. The percentages in each code from 1976 were compared to those from 1977, and the appropriate code was inferred where the majority of subjects worked in the same facility in 1976-1977. Some codes for place of employment had to be altered. For example, Vancouver General Hospital at times was coded as an extended care or long-term care facility. These nurses most likely worked in extended long-term care areas within the hospital; however, the facility itself was still considered a hospital (note: the information on specific nursing units was preserved through analyzing the field of employment codes). By examining how the majority of the nurses coded their facility, missing or incorrect “place of employment” codes could be selected and confirmed through web searches and contacting the facility in question, where possible. Place of employment categories changed often throughout the cohort period; for instance, “personal care” was reclassified as “home care agency” after 1981.

#### **4.4 National Mortality and Cancer Data Files**

##### **4.4.1 Canadian Mortality Database**

The Canadian Mortality Database is a computer-readable file of all deaths in Canada since 1950 and is administered by Statistics Canada. Information on over 190,000 deaths per annum are added to the data base (*Fair et al, 2001*). The probability of identifying deceased and living subjects from the data base was estimated to be 98.2% and 100% respectively (*Goldberg et al, 1993*). Completeness of reporting of age, sex, marital status, place of residence and cause of death was 99% for the period 1991-1995 (*Statistics Canada, 1997*).

The Occupational and Environmental Health Research Section of the Health Statistics Division of Statistics Canada is responsible for standardizing the data fields (e.g., names), generating fields required for record linkage, and creating duplicate mortality records, which contain data variations (e.g., alternative surnames) (*Health Statistics Division, 2003*). The information available from the death records for linkage include the death date (day, month, year), the death province, underlying cause of death, birth date, residence province or territory, and sex.

#### **4.4.2 National Cancer Registry**

The Canadian Cancer Registry is comprehensive and population-based, containing all cases of malignant cancer since 1969. It is maintained by the Health Statistics Division of Health Canada and utilizes multiple sources of ascertainment, including pathology and other laboratory reports, hospital records, death certificates and notifications from treatment clinics and private physicians (*Howe, 1994*). Statistics Canada obtains, edits, and standardizes cancer incidence records from provincial cancer registries and the health authorities of the three territories, and converts the data into the Registry (*Health Statistics Division, 2003*). The Cancer Registry is a patient-based system providing longitudinal information, where each type of cancer is recorded for a particular individual until death (*Statistics Canada, 2005a*).

#### **4.5 Linkage with Data Files**

Linkages to the national mortality database and cancer registry are performed by Statistics Canada using state-of-the-art probabilistic record linkage methodology. The RN cohort file was linked, using probabilistic linkage methods, to the Canadian Mortality Data Base to identify those who died during the study period (1974-2000) and to ascertain cause of death. Information from the income tax files was incorporated in the linkage to help determine vital status. The cohort file was also linked with the population-based National Cancer Registry (1969-1999) to identify RNs who were diagnosed with cancer and to ascertain their diagnoses. The linkages were based on a probabilistic record linkage called the generalized record linkage system (GRLS) developed at Statistics Canada (*Howe, 1998*). Scoring for GRLS was based upon agreements and disagreements on surname, given names, birth date, birth place, province and postal code of residence, and vital status (deceased or alive).

All cancer diagnoses and causes of mortality were classified using version 9 of the ICD classification system (ICD-9).

##### **4.5.1 Manual Resolution and Follow-Up**

The data manager travelled to Statistics Canada in Ottawa to resolve uncertain linkages of the RN cohort file to the Canadian Mortality Database and the Canadian Cancer Database. A Statistics Canada staff member provided training on strategies for manual

resolution. Information from the tax file was used to assist with the linkage, with a “key” using the following items for matching: sex, full date of birth, first five characters of the surname and the first four characters of the given name.

The social insurance numbers available from the cohort file were matched to the historic tax summary file to extract the records. Names and birth dates from the tax records were then compared to those from the cohort file to verify that the records were in fact referring to the same individual. False matches were removed. For those cohort records with an alive match, the following variables were appended to the nominal roll records; last tax year filed, filing province, date of death (if applicable), postal code, standard geographical code and an historical tax filing flag vector. These variables assisted with the record linkage process and also with the manual resolution of uncertain matches. Where a social insurance number was available, Statistics Canada conducted an “alive” follow-up, for the years 1984-2000 using summary tax files. Tables of summary information only were released, which gave counts of known alive subjects by calendar year groupings.

#### **4.6 Linkage to the National Dose Registry**

The National Dose Registry (NDR) has been maintained by Health Canada’s Radiation Protection Bureau since 1951 and consists of radiation exposure data of 550,000 workers from 25,000 institutions (*Sont et al, 2001*). The NDR has collected exposure information on 130,000 workers in over 80 occupations and 14 workplace categories, such as hospitals and power plants (*Health Canada, 2002*). The dosimetry badges are not distributed on a random basis.

The data provided by the National Dose Registry contained a total of 16,886 individual measurements as a result of linkage with the RN cohort file. The variables in coded form included the exposure year(s), province, class (e.g., hospital, industry), service type (e.g., monitoring frequency), employers, job class (most frequently denoted as “nurse”), doses (body, skin, or extremity), number of monitoring records for the year, and the first and last monitoring periods. Individual identifying information was replaced by a numeric code.

There were 665 measurements that had two or more cumulative doses for the same year, indicating different employers. To calculate person years, doses from multiple places of employment were added together. Thirty one measurements that included more than one year in the exposure-year code were modified by applying an equal portion of the total

reported dose to each year (e.g., if a dose had an exposure-year code of 195257 indicating exposure from 1952 to 1957, the dose was divided by 6 years).

Non-detectable measurements (reporting limit of detection was 0.20 mSv) were assigned values based on the method of Finkelstein *et al* (2001), which assumes that the data are log-normally distributed. This method produces unbiased estimates of the mean and standard deviation even with measurements below the detection limit.

## **4.7 Exposure Assessment**

### **4.7.1 Job Category Analysis**

For all cohort members, the work history file contained the date of initial registration in British Columbia, educational level and the following specific job information for each year the subjects were registered as RNs in the province: name of employer, type of employer, employment position, primary area of responsibility, full- or part-time status and nursing hours worked. “Job categories” were defined using three fields: place of employment (e.g., hospital), field of employment (e.g., oncology) and position of employment (e.g., staff nurse) (see Appendix I for an example of the detailed classifications).

Initially, four retired nurses and one senior nurse were asked to identify and group together specific job titles that they believed to be indistinguishable from each other, defined as having similar exposure to anaesthetic gases, antineoplastic drugs and ionizing radiation and having similar job duties/tasks. For example, “public health agency”, “community health centre” and “physician’s office/family practice unit” were grouped together. From the work history file, the variables, place, field, and position of employment were cross-tabulated to form linked cells (“place of employment/ field of employment/ position of employment”). Three senior nurses then worked independently to collapse the groupings into 30 to 50 job categories per year based on similar daily work routines and exposures. A total of 54 nursing job categories were created which were applicable to the entire period.

### **4.7.2 Health Care Facility Survey**

Exposure assessment to ascertain frequency and duration of exposure to anaesthetic gases, antineoplastic drugs, and ionizing radiation during the study period was based on

information gleaned from the hospital survey of all hospitals and health care centres in BC and a stratified random sample of long-term care/nursing homes, community health agencies and educational institutions.

The first draft of the survey was derived primarily from the published literature and was reviewed by the study team and two senior nurses. As recommended by the grant reviewers, a pilot study was conducted to investigate sources of information available on exposure hazards and as a guide to improving the questionnaire. The pilot study was administered at four local hospitals in the Vancouver area (departmental personnel interviewed were from OR, PARR, oncology, medical/surgical, ER, critical care, ambulatory care, maternal/newborn, pharmacy, occupational health and safety, and purchasing departments).

Initial contact letters were sent to the CEOs of the hospitals and health centres followed by telephone calls to the nurse managers. The managers provided further contact information for representative nurses from each relevant department (e.g., oncology, OR and medical/surgical nursing units). Most questionnaires were administered by telephone. A representative sample of personnel from other facilities such as long-term care, extended care, community care, mental health care, rehabilitation, private care, association /government facilities and educational institutions were also contacted.

At least one department representative was interviewed at all 94 hospitals (357 departments) and 19 health centres (including diagnostic and treatment centres). To confirm the absence of specific exposures, a random sub-sample of representatives of the following types of facilities were interviewed: extended care, long-term care, community health, rehabilitation/convalescent centres, associations/government, mental health centres, home care agencies, business/industry/occupational health agencies, and self employed nurses.

A brief description of the survey methods and results follows. Further details about the results of the survey and scientific literature pertaining to anaesthetic gases, antineoplastic drugs and ionizing radiation, are found in three earlier reports submitted to the Research Secretariat of the WCB (*Ward et al, 2005*).

### **4.7.3 Estimated Exposure to Specific Agents**

#### **4.7.3.1 Anaesthetic gases**

Most exposures to halogenated anaesthetic gases and nitrous oxide occurred in the ORs and PARRs. Because these departments were first noted in the work history files in 1990, analysis of mortality and cancer incidence relationships could not be undertaken (there were too few cases or deaths occurring between 1990 and 2000). During the 10-year period (1990 to 2000) it was estimated that 4,342 RNs were potentially occupationally exposed to anaesthetic gases in BC (i.e., at least 1 in 10 nurses of the 40,412 with work history data during that period). The proportion of RNs potentially exposed to anaesthetic gases slightly increased from 6.5% in 1990 to 8.7% in 2000.

Measurement data on anaesthetic gases, obtained from the Workers' Compensation Board of BC Laboratory, were based on compliance (non-random) sampling and consisted of over 500 measurements conducted by WCB occupational hygiene officers between 1981 and 2001. Anaesthetic gases monitored were mainly nitrous oxide and the halogenated gases, enflurane, halothane and isoflurane. Overall there were relatively few facilities in which measurements were made and they were not done consistently. About 60% of the measurements were below the limit of detection. For area samples, the mean levels of enflurane and nitrous oxide were higher in PARRs compared to ORs, while the opposite was true for halothane and isoflurane. For personal samples, levels of enflurane, halothane and nitrous oxide in ORs exceeded those measured in PARRs, while measurements of isoflurane were comparable. Nitrous oxide had the highest percentages of samples exceeding the WCB exposure limit in the OR (67%) and PARR (50%); however, the number of samples taken was very small.

#### ***4.7.3.2 Antineoplastic drugs***

The survey data were used to create categories of “no” “unlikely” “possible” or “probable” exposure to specific chemicals or radiation sources and were based primarily on the following elements (See algorithm, Appendix IIa).

- Job title-based exposure (no, possible, probable);
- Average number of patients per week administered antineoplastic drugs;
- Whether mixing antineoplastic drugs;
- Type of personal protective equipment used and special handling procedures followed.

Exposure to antineoplastic drugs primarily occurred within the oncology field. Because the work history field of employment included the option of “oncology” only after 1996, nurses who were noted to have been employed by cancer centres, between 1974 and 1995, were included with oncology nurses (provided that they worked in medical/surgical, other patient care or ambulatory care departments). Of the 54,928 RNs who had a work history between 1974 and 2000, a total of 7,635 (13.9%) were assigned as having potential exposure categorized as being “unlikely” “possible” or “probable” through their employment in facilities where antineoplastic drugs were used. The number of nurses potentially exposed stayed somewhat consistent over the years, with the highest numbers occurring in the most recent years.

The use of cytotoxic drugs is becoming more widespread, as according to the BC Cancer Agency Benefit Drug List, there was an increase from 66 to 99 different antineoplastic drugs between 1986 and 2000.

#### ***4.7.3.3 Ionizing radiation***

Exposure assessment for sources of ionizing radiation was handled in a manner similar to that applied to antineoplastic drugs using the same survey data (see algorithm, Appendix IIb). Of the 54,928 RNs who had a work history between 1974 and 2000, 15,472 (28.2%) were assigned as having possible or probable exposure to ionizing radiation. The number of nurses potentially exposed steadily increased over the time period, showing a peak in the number of RNs estimated to be probably exposed in 1995. According to the survey, portable x-ray equipment was reported as being the most frequently used; however, the use of protective equipment (lead shields, aprons and neck covers) while using portable machines was generally less common than with fixed x-ray or fluoroscopy equipment.

Another source of data for ionizing radiation exposure was the occupational dosimetry measurements obtained through the National Dose Registry.

#### ***4.7.3.4 Assigning exposure probabilities***

For antineoplastic drugs and ionizing radiation, an exponential weighting (0, 0.04, 0.16, and 0.64) was assigned to the exposure probabilities (none, unlikely, possible and probable exposure, respectively) via the algorithm in Appendix II. In addition, full-time

employment was assigned a weight of 1.0 and part-time a weight of 0.5. These weights were cumulated over the person's full exposure history, to give an estimated cumulative exposure probability in 'exposure-probability years', as follows:

$$\sum_{j=1}^n P_j \times H_j$$

Where  $P_j$  = weight for the assigned probability of exposure for that job/department/hospital/year (0= none, 0.04=unlikely, 0.16=possible, 0.64=probable)

$H_j$  = weight for full-time (=1) versus part-time (=0.5) hours of work

$j$  = specific job in specific department in specific hospital for a specific year

Based on the distribution, cumulative exposure years greater than zero were categorized as follows:

Minimal exposure =  $\leq 0.16$  exposure-probability years

Likely exposure =  $> 0.16$  exposure-probability years

#### **4.8 Statistical Analysis**

Standardized mortality ratios (SMRs) and standardized incidence ratios (SIRs) were used to compare cancer mortality and incidence, respectively for the study group to that of the BC population (*Breslow et al, 1987; Rothman et al, 1998*). The SMR (or SIR) was the ratio of the number of deaths (or cancer diagnoses) in the study cohort to that expected based on the population rates. A minimum of 3 cases was required for tables of specific causes of death or incidence of cancer.

The follow-up period for the mortality analysis was from January 1<sup>st</sup> 1974 to December 31<sup>st</sup>, 2000. BC mortality rates calculated by 5-year age groups and 5-year calendar periods for each cause of death for the years 1974 to 2000, were provided by Statistics Canada. The follow-up period for the cancer incidence analysis was from 1974 to 1999. Cancer incidence rates were calculated using data from the population-based BC Cancer Registry by the same 5-year age and calendar periods for the years 1974 to 1999. Person-years were calculated, using the Life Table Analysis System (PCLTAS) developed by the US National Institute for Occupational Safety and Health (NIOSH), from the point at which cohort members attained one year of employment until the end of follow-up, death, or date last known to be alive (*National Institute for Occupational Safety and Health, 2000; Steenland*

*et al, 1998*). When a specific cancer incidence site was examined, information on other cancer diagnoses was not used in censoring. Therefore, when more than one cancer site was diagnosed, each was analysed separately. Observations were censored for RNs lost to follow-up (i.e., no longer registered and known to have left Canada prior to the end of the study). Otherwise follow-up occurred until December 31, 2000 for mortality and 1999 for cancer incidence, unless there was a death recorded in the national mortality data base. The expected values were obtained using person years and the corresponding population rates.

Tests of significance of the SMRs and SIRs were calculated assuming the observed number of events followed a Poisson distribution with mean given by the expected number of events (*Breslow et al, 1987*), using two-sided testing with a 5 percent significance level corresponding to a 95% confidence interval. Thus, an effect was considered to be statistically significant if the p-value was less than 5% for a two-sided test. All cancer diagnoses and mortality cases classified according to the ICD-9 codes were included in the analyses (Appendix III).

Internal comparisons using cumulative years of employment in a job category were initially performed using standardized rate ratios (SRRs) on all outcomes based on initial cancer diagnoses. Where there was a minimum of 3 exposed cases and an elevated SRR (>1.5) or statistically significant results, the comparisons were finalized with Poisson regression analysis, with relevant parameters estimated with maximum likelihood methods using the R statistical software package (*The R Foundation for Statistical Computing Version 2.0.0, 2004*). Non-cancer causes of mortality only were evaluated.

For exposure analyses, multivariate analysis of an outcome was examined using Poisson regression with adjustment of the relative risk estimate by age and calendar year as potentially confounding factors. Cumulative years employed in specific job categories were calculated for each nurse and grouped into 3 categories (0, <5 years, and 5+ years). All internal comparisons of cancer incidence and causes of death incorporated a lag of 10 years to allow for latency subsequent to exposure. Thus, exposure within 10 years immediately prior to the diagnosed date or date of death was not considered in the cumulative estimate. Consideration of latency is especially relevant for most cancers and chronic diseases.

## 4.9 Ethics

Ethics approval of the project was originally obtained from the University of British Columbia's Clinical Research Ethics Board. The survey letter sent to hospital CEOs and interview questionnaire were approved by amendment in April 2002. Carrying out the retrospective cohort study protocol did not require contact with study subjects or their next of kin. The main ethical issue was confidentiality of records. All paper copy records and computer diskettes containing personal identifying information were kept in locked storage facilities. Computer files were accessible by password only, known to the principal investigator and the study data analyst. Because linked files were stripped of names, no reports or data analyses identified any individuals.

Three of five BC Regional Health Authorities required additional ethics approval. A package containing the following information was sent to the chair of the clinical research committee of each health authority: a letter explaining the study, a copy of the certificate of approval from the University of British Columbia's Clinical Research Ethics Board, the original grant proposal, the summary of the exposure assessment protocol, a copy of the questionnaire, and if necessary, a consent form. In addition, approval was required from six individual hospital ethics or research boards before any departments within the hospital could be contacted.

Linkages to the Canadian Mortality and Cancer Incidence databases were carried out by Statistics Canada under the protection of the Canadian Statistics Act, with individual records and outcome information returned to the researchers with the names removed. Ethics approval was obtained after an extended period of time through Statistics Canada, for each province where mortality and cancer incidence data were obtained. After all data linkages were completed, the personal identifiers were removed from the files. Receiving data from the National Dose Registry also required approval of the study by Health Canada. A conference call was undertaken involving the principal investigator and the ethics panel members.

## 5. RESEARCH FINDINGS

### 5.1 Description of the RN Cohort

There were a total of 58,125 RNs in the cohort, consisting of 1,912 males and 56,213 females (96.7%). The distribution of cohort members according to year of birth, year of registration and number of years registered as a RN are shown in Tables 1 to 3. The average age (and standard deviation) for females was 50.4±13.4 years compared to 44.9±10.7 years for males.

**Table 1. Distribution of the BC RN Cohort According to Year of Birth**

Year of Birth	All		Females		Males	
	n	%	n	%	n	%
1890-1899	5	0.0	5	0.0	0	0.0
1900-1909	108	0.2	108	0.2	0	0.0
1910-1919	1,427	2.5	1,421	2.5	6	0.3
1920-1929	3,448	5.9	3,414	6.1	34	1.7
1930-1939	6,753	11.6	6,648	11.8	105	5.4
1940-1949	14,107	24.3	13,686	24.4	421	21.6
1950-1959	18,231	31.4	17,586	31.3	645	33.1
1960-1969	10,794	18.6	10,207	18.2	587	30.1
1970-1979	3,208	5.5	3,057	5.4	151	7.7

**Table 2. Distribution of the BC RN Cohort According to Number of Years Registered as a Nurse in BC**

Years as a RN	All		Females		Males	
	n	%	n	%	n	%
2-9	18,906	32.5	17,889	31.8	1,017	52.2
10-19	16,077	27.7	15,486	27.6	591	30.3
20-29	12,218	21.0	11,912	21.2	306	15.7
30-39	8,198	14.1	8,165	14.5	33	1.7
40-49	2,534	4.4	2,532	4.5	2	0.1
50-59	166	0.3	166	0.3	0	0.0
60-69	26	<0.1	26	0.0	0	0.0

**Table 3. Distribution of the BC RN Cohort According to Year of Initial Registration in BC**

Year of Initial Registration	All		Females		Males	
	n	%	n	%	n	%
<1930	31	0.1	31	0.1	0	0.0
1930-1939	374	0.6	374	0.7	0	0.0
1940-1949	1,512	2.6	1,512	2.7	0	0.0
1950-1959	3,593	6.2	3,584	6.4	9	0.5
1960-1969	7,593	13.1	7,536	13.4	57	2.9
1970-1979	14,595	25.1	14,281	25.4	314	16.1
1980-1989	15,971	27.5	15,358	27.3	613	31.5
1990-1999	14,456	24.5	13,500	24.0	956	49.1

Medical/surgical nursing units were the most common field of employment among RNs who worked in hospitals. For non-hospital establishments the greatest percentage of nurses was employed in community health and long term/extended care nursing units. The highest education level attained was similar for males and females, the most common being diplomas (77.6% and 77.1%, respectively), followed by baccalaureate degrees (21.1% and 20.9%, respectively) and post-graduate degrees (2.0% for both genders).

Table 4 shows the differences between employment characteristics by gender. A greater percentage of males consistently worked full-time and worked in mental health as their field of employment. Note that the dashes indicate that no specific information was available for a field in the particular time period.

**Table 4. Description of the BC RN Cohort by Gender and Year**

	1980		1990		2000	
	Female	Male	Female	Male	Female	Male
N	24,102	425	31,324	895	30,803	1,283
Age Years (SD)	37.6 (11.1)	36.6 (8.2)	41.3 (10.4)	39.2 (8.5)	45.2 (10.0)	42.7 (9.4)
Average hours worked/year (SD)	1493.1 (482.8)	1752.9 (215.3)	1203.3 (533.9)	1389.7 (565.3)	1314.9 (553.7)	1519.9 (572.2)
	%					
Full time/part time status						
Full time	64.2	95.1	55.5	80.3	47.4	66.3
Part time	35.8	4.9	28.5	7.9	32.2	19.7
Casual	-	-	16.0	11.8	20.3	1.6
Place of employment						
Hospital	75.5	58.4	72.5	70.8	66.1	67.0
Community health	11.3	20.1	7.6	3.8	11.4	6.9
Long term/extended care	9.1	7.0	8.1	6.3	10.2	9.0
Doctor's office	0.8	0.0	2.3	0.0	2.0	0.4
Educational institution	1.0	1.4	2.5	1.8	2.6	0.9
Other	2.3	13.1	7.0	17.3	7.6	15.9
Field of employment						
Medical/surgical	26.8	14.1	26.7	27.7	20.2	23.3
Maternity	8.0	0.3	7.7	0.3	6.5	0.3
Paediatrics	4.3	1.7	4.2	1.9	2.9	1.0
Gerontology	9.6	6.6	12.7	9.6	14.6	13.1
Mental health	4.1	29.1	3.8	19.5	4.9	17.7
Medical/surgical specialties*	19.3	21.9	-	-	-	-
Critical care*	-	-	11.4	13.1	7.3	9.7
Oncology*	-	-	-	-	1.3	1.1
OR/PARR*	-	-	4.6	3.0	6.4	3.6
Emergency*	-	-	2.6	4.9	4.7	7.6
Other	27.9	26.2	26.1	20.1	31.2	22.6
Position of employment						
Staff nurse	78.8	62.5	80.3	77.1	80.5	81.4
Head/charge nurse	6.5	14.4	5.7	10.1	-	-
Manager	3.6	7.8	2.5	3.1	5.8	8.3
Clinical nurse specialist	7.8	1.2	1.0	0.7	1.2	1.3
Other	10.6	14.1	10.5	11.2	12.5	9.0

\* Medical/surgical specialties (1979-2000); Critical care (1988-2000); Oncology (1996-2000); OR/PARR (1990-2000); Emergency (1992-2000). Also see Section 4.2.

### **5.1.1 RN Cohort-NDR Linked Data**

Of the 58,125 nurses in the cohort, 3,470 nurses were found to have radiation exposure data in the Dose Registry, with a total of 16,246 person-years of measurements (Appendix IVa). Most of these years of exposure (13,973 person-years; 86%) were during the study period of the cohort (1974 to 2000), and 43% (7,028 person-years) were during employment as a registered nurse within BC. The highest number of yearly doses measured was 726 in 1990, which contrasts to only 236 taken in 2000. Most of the measurements (78%) were below the detection limit of 0.20 mSv. However, 40% of the nurses had at least one monitoring period with detectable exposure to radiation. There were comparatively few measurements done prior to 1970 and the average doses for this period were relative high.

It is important to note that the badges were not distributed randomly. When stratified by place of employment, rehabilitation/convalescent centres had an average dosage that was over double that of other places of employment (Appendix IVb). The largest number of measurements was in a hospital setting.

RNs working in oncology had average exposures five times higher than other fields of employment (Appendix IVc); unfortunately this department was not recorded in the RNABC registration forms prior to 1996. The largest dosage of radiation (66 mSv) was found for a nurse working in an oncology department.

For position of employment, the largest number of readings was for staff nurses (74.3%). The positions of employment with the greatest average dose, apart from the indeterminate “Other” category, were that of clinical nurse specialists and head nurses (Appendix IVd). The lowest doses were found for administrators.

A comparison of the two methods used to assign exposure to ionizing radiation to the cohort, for the years 1977, 1987, and 1997, is shown in Appendix IVe. There is little congruence between the methods; for example, the majority of nurses with detectable doses of ionizing radiation were classified as having no probability of exposure. Between-hospital differences in the proportions of nurses who wore badges also were found (data not shown).

### **5.2 Causes of death - Standardized Mortality Ratios**

During the mortality follow-up period between 1974 and 2000, 2157 female and 81 male members of the cohort died. Confirmed causes of death were available for over 99%.

The SMR was 0.61 (90% CI, 0.59-0.63) for all causes of mortality, indicating that there was a strong “healthy worker” effect for the cohort of female registered nurses. Cancer was the dominant cause of death in the female cohort (Table 5). The most common types of cancer causing death for female RNs were breast and lung, but the respective SMRs (0.87 and 0.56) were significantly lower when rates were compared to that of the general population, particularly for lung cancer. The only elevated SMR (>1.5) was for cancer of ‘other endocrine glands’ (includes the thymus, adrenal and parathyroid glands), although this was not statistically significant.

Statistics Canada provided aggregate information on the percentage of nurses who were not residing in Canada by year and age group. The assumption was that December 30, 2000 was the last date of follow-up (unless the date of death or cancer incidence was known, or last year in Canada was known using RNABC registry data). Based on that assumption the number of expected female deaths was found to be overestimated by 163, given the new summary information. The revised SMR would change only slightly to 0.64 (2,153/(3533-163)), in comparison to our finding of 0.61.

**Table 5. Cancer Mortality (Standardized Mortality Ratios) for Female RNs in BC in Comparison to the BC General Population**

Type of Cancer	Observed	Expected	SMR	95% Confidence Interval
Breast	274	314.16	0.87	0.77-0.98
Lung	169	302.19	0.56	0.48-0.65
Large Intestine except Rectum	110	116.64	0.94	0.77-1.13
Ovary/Fallopian Tube/Broad Ligament	91	93.99	0.97	0.78-1.19
Pancreas	50	63.52	0.79	0.59-1.04
Ill-defined Cancer <sup>1</sup>	45	66.52	0.68	0.50-0.91
Non-Hodgkin’s Lymphomas	44	42.32	1.04	0.76-1.40
Uterus including Cervix	35	66.78	0.52	0.36-0.72
Brain & Nervous System	33	44.77	0.74	0.51-1.04
Malignant Melanoma	27	21.33	1.27	0.84-1.85
Stomach	23	34.27	0.67	0.42-1.01
Lymphatic & Myeloid Leukaemia	22	28.33	0.78	0.49-1.18

Rectum & Rectosigmoid Junction	14	24.39	0.57	0.31-0.96
Esophagus	13	16.53	0.79	0.42-1.35
Multiple Myeloma	13	18.73	0.69	0.37-1.18
Gallbladder	12	13.78	0.87	0.45-1.52
Bladder & Other Urinary	12	12.54	0.98	0.51-1.71
Liver	10	12.07	0.83	0.40-1.53
Kidney	10	19.64	0.51	0.24-0.94
Other & Unspecified Leukaemia <sup>2</sup>	8	10.88	0.74	0.32-1.46
Other Endocrine Glands <sup>3</sup>	6	2.96	2.03	0.74-4.42
Other Female Genitals <sup>4</sup>	5	3.83	1.31	0.43-3.06
Connective Tissue	4	8.95	0.45	0.12-1.15
Small Intestine	3	2.93	1.02	0.21-2.98
Thyroid	3	3.75	0.80	0.16-2.34
All Cancers	1051	1386.02	0.76	0.71-0.81
All Deaths	2157	3536.55	0.61	0.58-0.64

<sup>1</sup> Cancers of the head, face, neck, thorax, abdomen, pelvis, upper limb, lower limb, back, flank and trunk.

<sup>2</sup> Acute erythremia and erythroleukaemia, chronic erthremia, megakaryocytic leukaemia, lymphosarcoma cell leukaemia.

<sup>3</sup> Includes cancers of the thymus, adrenal and parathyroid glands.

<sup>4</sup> Includes cancers of the vagina, labia majora and labia minora.

For female RNs, all non-cancer causes of death were lower in number than expected. Significantly low SMRs of approximately one-half the risk were found for cardiovascular-related causes of death including acute myocardial infarction, ischemic heart disease and cerebrovascular disease, as well as for chronic obstructive pulmonary disease (Table 6).

**Table 6. Non-cancer Mortality (Standardized Mortality Ratios) for Female RNs in BC in Comparison to the BC General Population**

<b>Cause of Death</b>	<b>Observed</b>	<b>Expected</b>	<b>SMR</b>	<b>95% Confidence Interval</b>
Acute Myocardial Infarction	141	253.43	0.56	0.47-0.66
Cerebrovascular Disease	127	239.35	0.53	0.44-0.63
Ischemic Heart Disease	76	172.04	0.44	0.35-0.55
Other Circulatory Disease <sup>1</sup>	71	114.77	0.62	0.48-0.78
Motor Vehicle Traffic Accident	66	95.29	0.69	0.53-0.88
Nervous System/Sense Organ Disease	65	86.00	0.76	0.61-1.01
Suicide	62	96.92	0.64	0.49-0.82
Chronic Obstructive Pulmonary Disease	45	88.11	0.51	0.37-0.68
Symptoms/Ill-Defined <sup>2</sup>	41	73.50	0.56	0.40-0.76
Pneumonia	39	80.39	0.49	0.35-0.67
Other Digestive Diseases <sup>3</sup>	37	75.43	0.49	0.35-0.68
Disease of Arteries, Arterioles & Capillaries	35	47.46	0.74	0.52-1.03
Mental Disorder	32	53.94	0.59	0.40-0.83
Other Accidents or Violence <sup>4</sup>	28	45.39	0.62	0.40-0.90
Accidental Falls	23	28.81	0.80	0.51-1.20
Diabetes Mellitus	19	65.41	0.29	0.17-0.45
Disease of Veins, Lymphatics & Other	19	24.26	0.78	0.47-1.22
Cirrhosis of Liver	19	87.78	0.22	0.13-0.34
Rheumatic Heart Disease, Including Fever	15	38.14	0.39	0.22-0.64
Other Respiratory System Diseases <sup>5</sup>	15	28.81	0.52	0.29-0.86
Kidney Diseases	15	35.79	0.42	0.24-0.69
Infective & Parasitic Diseases <sup>6</sup>	11	43.29	0.25	0.12-0.45
Other Endocrine/Metabolic <sup>7</sup>	13	23.01	0.56	0.30-0.96
Accidental Poisoning	10	58.56	0.17	0.08-0.31
Asthma	9	15.24	0.59	0.27-1.12
Musculoskeletal Disease	9	26.94	0.33	0.15-0.63

MVTA Involving Pedestrian	9	15.88	0.57	0.26-1.08
Neoplasm of Unspecified Nature <sup>8</sup>	8	5.47	1.46	0.63-2.88
Hypertensive Disease	8	17.05	0.47	0.20-0.93
Blood Diseases	7	11.15	0.63	0.25-1.30
Accidental Drowning	6	11.00	0.55	0.20-1.20
Ulcers	3	10.34	0.29	0.06-0.85
Other Genitourinary Disease <sup>9</sup>	3	7.40	0.41	0.08-1.20
Homicide	3	23.89	0.13	0.03-0.38
All Other Causes of Death <sup>10</sup>	13	24.39	0.53	0.28-0.91
All Deaths	2157	3536.55	0.61	0.58-0.64

<sup>1</sup> Includes acute pulmonary heart disease, certain pulmonary, aortic and mitral valve disorders.

<sup>2</sup> Includes fevers with unknown origin, chronic fatigue syndrome, undiagnosed heart murmurs, gangrene of the cardiovascular system and senility without mention of psychosis.

<sup>3</sup> Includes diseases of the oral cavity, salivary glands, and jaw (e.g., gingivitis), gastritis, duodenitis, appendicitis, gastrointestinal haemorrhage and acute and chronic pancreatitis.

<sup>4</sup> Includes fractures of the head, neck and trunk, lower limb, open wounds, poisoning by various substances (e.g. central nervous system stimulants), and crushing injuries of multiple and unspecified sites.

<sup>5</sup> Includes bronchiectasis, respiratory conditions from fumes and vapors and ulcers of bronchus or trachea.

<sup>6</sup> Excludes only silico-tuberculosis.

<sup>7</sup> Including disorders of the thymus, adrenal, parathyroid, thyroid and pancreas and obesity.

<sup>8</sup> Includes neoplasms of uncertain behaviour of the digestive and respiratory systems, genitourinary organs, endocrine glands and nervous system.

<sup>9</sup> Includes cystitis, urethritis, disorders of menstruation, menopause, and post menopause,

<sup>10</sup> Includes complications, not elsewhere classified, of electroshock and inhalation therapy, and unspecified misadventure of medical care.

Because males comprised only 3.7% of the cohort, there were relatively few deaths over the follow-up period (81 vs. 2157 deaths for female RNs). The SMR among male RNs was significantly elevated for “other infective and parasitic diseases” mostly attributed to Acquired Immune Deficiency Syndrome (Table 7).

**Table 7. Causes of Mortality (SMRs) for Male RNs in BC in Comparison to the BC General Population**

Cause of Death	Observed	Expected	SMR	95% Confidence Interval
Other Infective & Parasitic Diseases <sup>1</sup>	25	4.26	5.86	3.79-8.65
Suicide	6	5.99	1.00	0.37-2.18
Ischemic Heart Disease	5	4.77	1.05	0.34-2.45
Acute Myocardial Infarction	4	7.64	0.52	0.14-1.33
Accidental Poisoning	4	3.68	1.09	0.30-2.79
Nervous System/Sense Organ Disease	3	1.22	2.46	0.51-7.19
Other Digestive Diseases <sup>2</sup>	3	1.20	2.49	0.51-7.28
Motor Vehicle Traffic Accident	3	4.28	0.70	0.14-2.05
Other Accidents or Violence <sup>3</sup>	3	3.46	0.87	0.18-2.54
All Cancers (Mortality)	14	19.61	0.71	0.39-1.19
All Deaths	81	81.05	1.00	0.79-1.24

<sup>1</sup> Excludes only silico-tuberculosis.

<sup>2</sup> Includes diseases of the oral cavity, salivary glands, and jaw (e.g. gingivitis), gastritis, duodenitis, appendicitis, gastrointestinal haemorrhage and acute and chronic pancreatitis.

<sup>3</sup> Includes fractures of the head, neck and trunk, lower limb, open wounds (e.g. animal bites), poisoning by various substances (e.g. central nervous system stimulants), and crushing injuries of multiple and unspecified sites.

### 5.3 Cancer - Standardized Incidence Ratios

During the cancer incidence follow-up period between 1974 and 2000, 3062 female and 46 male RNs were diagnosed with cancer; all were confirmed cases. Among the 3062 cancer diagnoses for female RNs, 2712 cases (88.6%) were in British Columbia. The remaining cases (11.4%) were diagnosed in Alberta (120 Cases), Saskatchewan (30 Cases), Manitoba (17 Cases), Ontario (136 Cases), Quebec (17 Cases), New Brunswick (7 Cases), Nova Scotia (16 Cases), Prince Edward Island (2 Cases) and Yukon and Northwest Territories (5 Cases). The incidence of all cancers for the cohort of female RNs was significantly low compared to the BC population (SIR 0.91) (Table 8). Breast cancer was the most common type of cancer (40% of the incident cases) and had a slightly higher incidence rate for RNs compared to the BC population, along with cancer of the large

intestine. Malignant melanoma was the only cancer that had a significantly elevated risk (SIR 1.27). Significantly lower SIRs were observed for cancer of the uterus including cervix, as well as lung and kidney cancer.

**Table 8. Cancer Incidence (Standardized Incidence Ratios) for Female RNs in BC in Comparison to the BC General Population**

Type of Cancer	Observed	Expected	SIR	95% Confidence Interval
Breast	1286	1227.15	1.05	0.99-1.11
Uterus including Cervix	306	365.99	0.84	0.75-0.94
Large Intestine except Rectum	238	210.09	1.13	0.99-1.28
Lung	216	368.89	0.59	0.51-0.67
Malignant Melanoma	206	162.78	1.27	1.10-1.46
Ovary/Fallopian Tube/Broad Ligament	150	158.84	0.94	0.80-1.10
Rectum & Rectosigmoid Junction	130	122.69	1.06	0.89-1.26
Non-Hodgkins Lymphomas	128	111.32	1.15	0.96-1.37
Ill-defined Cancer <sup>1</sup>	89	88.17	1.01	0.81-1.24
Thyroid	86	76.14	1.13	0.90-1.40
Bladder & other Urinary	85	71.67	1.19	0.95-1.47
Pancreas	53	59.46	0.89	0.67-1.16
Brain & other Nervous System	47	53.79	0.87	0.64-1.16
Stomach	36	47.69	0.75	0.53-1.04
Kidney	38	53.18	0.71	0.50-0.97
Myeloid Leukaemia	36	29.67	1.21	0.85-1.68
Multiple Myeloma	35	29.67	1.18	0.82-1.64
Hodgkin's Disease	22	24.71	0.89	0.56-1.35
Lymphatic Leukaemia	21	20.52	1.02	0.63-1.56
Gallbladder	20	19.09	1.05	0.64-1.62
Connective Tissue	18	19.00	0.95	0.56-1.50
Other female genital organs <sup>2</sup>	17	23.17	0.73	0.43-1.17
Esophagus	15	17.05	0.88	0.49-1.45

Liver	13	16.05	0.81	0.43-1.39
Mouth	10	16.59	0.60	0.29-1.10
Small Intestine	9	6.66	1.35	0.62-2.56
Other Endocrine <sup>3</sup>	8	4.70	1.70	0.73-3.35
Other & Unspecified Leukaemia <sup>4</sup>	8	6.89	1.16	0.50-2.29
Tongue	7	14.11	0.50	0.20-1.03
Bone	7	6.58	1.06	0.43-2.18
Oropharynx	5	7.58	0.66	0.21-1.54
Peritoneum	5	7.95	0.63	0.20-1.47
Eye	4	7.91	0.51	0.14-1.31
Lip	4	3.45	1.16	0.32-2.97
Salivary Gland	4	7.72	0.52	0.14-1.33
Nose/Sinuses	3	5.41	0.56	0.12-1.64
All Cancers	3062	3347.92	0.91	0.88-0.94

<sup>1</sup> Includes cancers of the head, face, neck, thorax, abdomen, pelvis, upper limb, lower limb, back, flank and trunk and secondary unspec. malignant neoplasm of lymph nodes, respiratory and digestive systems.

<sup>2</sup> Includes cancers of the vagina, labia majora and labia minora.

<sup>3</sup> Includes cancers of the thymus, adrenal and parathyroid glands.

<sup>4</sup> Acute and chronic erythremia erythroleukaemia, megakaryocytic leukaemia, lymphosarcoma cell leukaemia.

For males, there were no consistent trends, or statistically significant results observed for risks of cancer incidence, based on the small number of cancer incident cases (Table 9). Prostate cancer was the most common malignancy.

**Table 9. Cancer Incidence (Standardized Incidence Ratios) for Male RNs in BC in Comparison to the BC General Population**

<b>Cause of Death</b>	<b>Observed</b>	<b>Expected</b>	<b>SMR</b>	<b>95% Confidence Interval</b>
Prostate	8	7.49	1.07	0.46-2.11
Rectum and Rectosigmoid Junction	4	2.38	1.68	0.46-4.30
Lung	4	6.74	0.60	0.16-1.54
Kidney	4	1.61	2.48	0.68-6.35
Malignant Melanoma	4	7.16	0.60	0.16-1.54
Non-Hodgkin's Lymphoma	4	2.98	1.35	0.37-3.46
Bladder and Other Urinary	3	2.77	1.10	0.23-3.21
All Cancers (Incidence	46	43.52	1.06	0.78-1.41

#### **5.4 Cancer Incidence for Female RNs According to Years Worked as a Nurse**

Analysis of years worked as a nurse was conducted using 10 year lags in order to take latency into account. The relative risks for breast cancer and lung cancer were significantly elevated after 25 years of work (Table 10). The incidence of malignant melanoma and rectal cancer peaked at 15-25 years working as a nurse. Although the trends did not show a monotonic increase for each cumulative years of work category, the tests for trend was statistically significant for malignant melanoma and lung cancer.

**Table 10. Relative Risks for Cancer Incidence Among Female RNs According to Years Worked as a Nurse**

Type of Cancer	Cumulative Years of Work	Observed	Expected	RR	95% Confidence Interval	Trend Test P-value
Breast	<i>0-5</i>	374	400.51	1.00		0.075
	<i>5-15</i>	379	368.99	1.14	0.98-1.33	
	<i>15-25</i>	269	257.73	1.05	0.87-1.25	
	<i>25+</i>	264	199.92	1.28	1.04-1.59	
Malignant melanoma	<i>0-5</i>	90	81.78	1.00		0.013
	<i>5-15</i>	56	43.60	1.37	0.99-2.06	
	<i>15-25</i>	40	22.29	2.05	1.22-3.45	
	<i>25+</i>	20	14.81	1.89	0.90-3.98	
Lung	<i>0-5</i>	28	79.88	1.00		0.030
	<i>5-15</i>	48	89.06	1.59	0.98-2.59	
	<i>15-25</i>	52	90.66	1.59	0.96-2.61	
	<i>25+</i>	88	109.28	1.90	1.14-3.14	
Rectum	<i>0-5</i>	22	28.85	1.00		0.116
	<i>5-15</i>	29	29.49	1.32	0.74-2.36	
	<i>15-25</i>	41	30.54	1.93	1.08-3.47	
	<i>25+</i>	38	33.81	1.51	0.79-2.91	

## 5.5 Mortality and Cancer Incidence of Female RNs by Field of Employment

Analysis of the linked cell job categories yielded insufficient cancer cases and deaths to allow for the evaluation of exposure-response relationships. The following fields of specialized employment areas were analyzed: medical/surgical specialties (includes OR, PARR, critical care, emergency and other patient care; 1979-2000), maternal newborn/paediatrics, OR/PARR (1990-2000) and cancer centres (1974-2000) combined with oncology (1996-2000). Causes of death and cancer incidence, as shown in Tables 11 to 14, were limited to statistically significant associations for at least one exposure category and where there were at least 3 exposed cases. Because internal comparisons based on cumulative years working in a particular job category were limited to working years since 1974, some misclassification will result from the lack of information on work prior to 1974 in that job category.

As seen in Table 11, RNs who had worked under 5 years in maternal newborn or paediatric nursing departments during 1974-2000 had significantly increased risks for death from chronic obstructive pulmonary disease (RR 2.93; 8 deaths) and significantly increased incidence of leukaemia (RR 2.16; 9 cases) and oesophageal cancer (RR 4.20; 4 cases). Working more than 5 years in that period was associated with a significantly elevated risk for cancer of the pancreas (RR 3.92; 4 cases). Having ever worked maternal newborn and paediatrics nursing units also was associated with an increased risk of mortality from blood diseases and gall bladder cancer, based on 3 and 5 exposed cases, respectively.

**Table 11. Relative Risks Among Female RNs According to Employment in Maternal Newborn or Paediatrics (1974-2000)**

	Years of Work in Maternal/Newborn & Paediatrics	Observed	Expected	RR	95% Confidence Interval
<b>MORTALITY</b>					
Blood Diseases	<i>Never worked</i>	4	10.19	1.00	
	<i>Worked &lt;5 years</i>	2	0.74	5.18	0.92-29.00
	<i>Worked 5+ years</i>	1	0.22	6.72	0.70-64.21
	<i>Ever worked</i>	3	0.96	5.59	1.20-25.95

Chronic Obstructive Pulmonary Disease	<i>Never worked</i>	37	79.43	1.00	
	<i>Worked &lt;5 years</i>	8	6.12	2.93	1.36-6.30
	<i>Worked 5+ years</i>	0	2.56	-	
	<i>Ever worked</i>	8	8.68	2.09	0.96-4.51
<b>CANCER INCIDENCE</b>					
Oesophagus	<i>Never worked</i>	11	15.40	1.00	
	<i>Worked &lt;5 years</i>	4	1.23	4.20	1.31-13.40
	<i>Worked 5+ years</i>	0	0.42	-	
	<i>Ever worked</i>	4	1.65	3.06	0.95-9.79
Gall Bladder	<i>Never worked</i>	15	17.27	1.00	
	<i>Worked &lt;5 years</i>	4	1.39	3.05	0.98-9.50
	<i>Worked 5+ years</i>	1	0.43	2.34	0.30-18.38
	<i>Ever worked</i>	5	1.83	2.88	1.01-8.24
Pancreas	<i>Never worked</i>	44	53.67	1.00	
	<i>Worked &lt;5 years</i>	5	4.36	1.55	0.60-3.97
	<i>Worked 5+ years</i>	4	1.43	3.92	1.35-11.35
	<i>Ever worked</i>	9	5.79	2.10	1.00-4.42
Leukaemia	<i>Never worked</i>	52	53.11	1.00	
	<i>Worked &lt;5 years</i>	9	4.17	2.16	1.04-4.48
	<i>Worked 5+ years</i>	1	1.14	0.82	0.11-6.06
	<i>Ever worked</i>	19	5.32	1.86	0.92-3.76

There was an elevated risk of lung cancer (RR 2.57; 14 cases) associated with working under 5 years in medical/surgical specialty nursing departments, (including OR, PARR, critical care, emergency and other patient care), as well as a higher risk of chronic obstructive pulmonary disease (RR 2.91; 5 cases) (Table 12). The risk of death due to blood diseases, diseases of the veins and lymphatics and of other endocrine metabolic diseases

was elevated, but there were only 3 to 4 cases each of RNs ever exposed who died of one of those diseases.

**Table 12. Relative Risks Among Female RNs According to Employment in Medical/Surgical Specialties (1979-2000)**

	Years of Work in Medical/Surgical Specialties	Observed	Expected	RR	95% Confidence Interval
<b>MORTALITY</b>					
Blood Diseases	<i>Never worked</i>	4	10.52	1.00	
	<i>Worked &lt;5 years</i>	2	0.47	8.41	1.50-47.08
	<i>Worked 5+ years</i>	1	0.12	10.20	1.06-97.90
	<i>Ever worked</i>	3	0.63	8.91	1.92-41.44
Chronic Obstructive Pulmonary Disease	<i>Never worked</i>	40	82.42	1.00	
	<i>Worked &lt;5 years</i>	5	3.85	2.91	1.14-7.37
	<i>Worked 5+ years</i>	0	1.85		
	<i>Ever worked</i>	5	5.70	1.95	0.76-4.96
Disease of Veins and Lymphatics	<i>Never worked</i>	15	22.73	1.00	
	<i>Worked &lt;5 years</i>	2	1.14	2.62	0.59-11.70
	<i>Worked 5+ years</i>	2	0.39	6.43	1.41-29.29
	<i>Ever worked</i>	4	1.53	3.72	1.20-11.49
Other Endocrine <sup>1</sup>	<i>Never worked</i>	10	21.63	1.00	
	<i>Worked &lt;5 years</i>	2	1.01	3.91	0.84-18.25
	<i>Worked 5+ years</i>	1	0.38	4.45	0.55-36.15
	<i>Ever worked</i>	3	1.38	4.07	1.09-15.23
<b>CANCER INCIDENCE</b>					
Lung	<i>Never worked</i>	202	358.94	1.00	
	<i>Worked &lt;5 years</i>	14	9.92	2.57	1.46-4.53
	<i>Worked 5+ years</i>	0	0.02		
	<i>Ever worked</i>	14	9.94	2.57	1.46-4.53

<sup>1</sup> Includes cancers of the thymus, adrenal and parathyroid glands.

Nursing in gerontology for less than 5 years was also associated with a significantly higher risk of death from rheumatic heart disease (RR 4.01; 3 cases); those working for at least 5 years in gerontology had a higher risk of diabetes (RR 6.51; 4 cases). (Table 13) A very high incidence of other endocrine cancer (including thymus, adrenal and parathyroid glands) was consistently found for all exposure groups.

**Table 13. Relative Risks Among Female RNs According to Employment in Gerontology (1974-2000)**

Cause of Death	Years of Work in Gerontology	Observed	Expected	RR	95% Confidence Interval
<b>MORTALITY</b>					
Diabetes	<i>Never worked</i>	13	53.80	1.00	
	<i>Worked &lt;5 years</i>	3	9.47	1.57	0.42-5.85
	<i>Worked 5+ years</i>	3	2.14	6.51	1.64-25.85
	<i>Ever worked</i>	6	11.61	2.45	0.86-7.03
Rheumatic Heart Disease	<i>Never worked</i>	9	33.79	1.00	
	<i>Worked &lt;5 years</i>	6	3.63	4.01	1.29-12.42
	<i>Worked 5+ years</i>	0	0.72	-	
	<i>Ever worked</i>	6	4.35	3.12	1.02-10.04
<b>CANCER INCIDENCE</b>					
Other Endocrine <sup>1</sup>	<i>Never worked</i>	2	4.26	1.00	
	<i>Worked &lt;5 years</i>	4	0.38	51.32	7.76-339.30
	<i>Worked 5+ years</i>	2	0.06	227.18	19.13-2697.75
	<i>Ever worked</i>	6	0.44	57.46	9.37-352.34

<sup>1</sup> Includes cancers of the thymus, adrenal and parathyroid glands

Although employment in the mental health field was not associated with any elevated risk of cancer, the risk of dying from acute myocardial infarction was over twice as high for those working under 5 years (RR 2.56; 14 cases), as was the risk of suicide (RR 3.03; 5 cases) (Table 14). Ever being employed in that field during the period 1974-2000 was associated with having chronic obstructive lung disease (RR 2.48; 6 cases).

**Table 14. Relative Risks Among Female RNs According to Employment in Mental Health (1974-2000)**

Cause of Death	Years of Work in Mental Health	Observed	Expected	RR	95% Confidence Interval
<b>MORTALITY</b>					
Acute Myocardial Infarction	<i>Never worked</i>	127	241.59	1.00	
	<i>Worked &lt;5 years</i>	14	9.38	2.56	1.47-4.47
	<i>Worked 5+ years</i>	0	2.46	-	
	<i>Ever worked</i>	14	11.83	2.05	1.17-3.57
Chronic Obstructive Pulmonary Disease	<i>Never worked</i>	39	83.08	1.00	
	<i>Worked &lt;5 years</i>	4	3.86	2.16	0.77-6.06
	<i>Worked 5+ years</i>	2	1.18	3.59	0.85-15.06
	<i>Ever worked</i>	6	5.04	2.48	1.05-5.90
Suicide	<i>Never worked</i>	57	94.65	1.00	
	<i>Worked &lt;5 years</i>	5	1.94	3.03	1.19-7.74
	<i>Worked 5+ years</i>	0	0.34	-	
	<i>Ever worked</i>	5	2.27	2.56	1.00-6.54

### 5.6 Exposure Ascertainment for the Relationship of Specific Exposures with Cancer Incidence

Because of the short time interval (1990-2000) for which pertinent field of employment information was available concerning exposure to anaesthetic gases, there were insufficient numbers of cases to allow for further analysis. Estimates concerning the probability of exposure to antineoplastic drugs during the period of 1974-2000 were not related to cancer incidence. However, comparison of ever versus never working in a cancer centre or in oncology showed a significant increase of breast cancer (RR 1.83; 95% CI 1.03-3.23; 12 cases).

RNs that ever had exposure to sources of ionizing radiation had a significantly increased risk of breast cancer (RR 1.21; 140 cases) (Table 15). There was an elevated risk of leukaemia for those classified as having minimal exposure to ionizing radiation (RR

2.75; 5 cases); specifically it was the risk of lymphatic leukaemia that was consistently high for minimal and likely exposure to sources of ionizing radiation., but with the highest risk (OR 9.70; 4 cases) for minimal exposure. For the subset of BC RNs for whom ionizing radiation dosimetry measurements were available, there was an elevated risk of bladder cancer (including in-situ) (RR 6.31, 95% CI 1.55-26.17) but it was based only on 2 cases and was for those wearing dosimetry badges, but having measurements that were less than the limit of detection.

**Table 15. Relative Risks for Cancer Incidence According to Potential Exposure to Ionizing Radiation (based on survey)**

Type of Cancer	Cumulative Probability of Work Exposure	Observed	Expected	RR	95% Confidence Interval
Breast (invasive)	<i>No Exposure</i>	1146	1120.17	1.00	
	<i>Minimal Exposure</i>	54	42.58	1.17	0.89-1.54
	<i>Likely Exposure</i>	86	64.40	1.23	0.99-1.54
	<i>Ever Exposure</i>	140	106.98	1.21	1.01-1.45
Leukaemia	<i>No Exposure</i>	54	54.05	1.00	
	<i>Minimal Exposure</i>	5	1.76	2.75	1.08-7.02
	<i>Likely Exposure</i>	3	2.61	1.10	0.34-3.60
	<i>Ever Exposure</i>	8	4.38	1.76	0.81-3.83
Lymphatic Leukaemia	<i>No Exposure</i>	14	18.91	1.00	
	<i>Minimal Exposure</i>	4	0.64	9.70	3.04-30.92
	<i>Likely Exposure</i>	3	0.97	4.86	1.31-18.02
	<i>Ever Exposure</i>	7	1.62	6.86	2.57-18.31

## 6. DISCUSSION

The cohort study design allowed for the investigation of rare health outcomes, such as cancer, with appropriate study power, as afforded by the large sample size of 58,125 subjects and follow-up of 27 years. There was sufficient identifier information available for

the cohort to effectively link with established national databases, which have excellent ascertainment for mortality and cancer incidence across the country.

The SMR for all causes of death was 0.61 for BC female RNs. The low value may in part be attributed to a “healthy worker effect” which is commonly found in studies of workers when compared to the general population. It does not appear to be an artifact of incomplete follow-up of the cohort as there was little difference in the overall SMR when adjusted for vital status according to tabulated follow-up information provided by Statistics Canada. Several studies have shown comparable results of low SMRs for nurses and other medical professionals including the Estonian study of female physicians by Innos *et al* (2000) (SMR 0.55, 95% CI 0.50-0.61) and a British study of female physicians (Carpenter *et al*, 1997) (SMR 0.55, 95% CI 0.47-0.63). A low SMR for all causes of death was observed for American non-military nurses (SMR 0.87; 95% CI 0.76-0.99) (Dalager *et al*, 1995) and for Icelandic nurses (SMR 0.77, 95% CI 0.65-0.90) when compared to the respective countries’ general population (Gunnarsdottir *et al*, 1995a).

The Icelandic study confirmed current findings of low risks of death from specific cancers among female nurses, including that of the cervix, lung, pancreas, ovary and stomach, the latter being statistically significant. Low SMRs were also observed for non-cancer causes of mortality including accidents, poisoning and violence and respiratory disease; the SMR was found to be significantly lower for ischemic heart disease. In our study, SMRs were significantly lower for the more common cancers of breast, lung, and uterus, including cervix. Almost all non-cancer causes of death were significantly lower including acute myocardial infarction, cerebrovascular disease, ischemic heart disease motor vehicle traffic accidents, suicide and chronic obstructive pulmonary disease. These findings of a lower risk of mortality in comparison to the general population suggest that nurses in general may have a healthier lifestyle, such as low smoking prevalence rates and better dietary habits. According to Canadian and American studies (Chalmers *et al*, 2000; Trinkoff *et al*, 1998; Hu *et al*, 2000); approximately 16-18% of registered nurses were current smokers and 21-24% were former smokers, compared to 22.9% and 39.2%, respectively, for the Canadian general population in 2003 (Statistics Canada, 2005b). Results from the Nurses’ Health Study and other American studies have shown that nurses are increasingly adopting healthful lifestyles by smoking less and choosing healthier diets,

which has resulted in a substantial improvement in cardiovascular health (*Hu et al, 2000; Dracup et al, 2002*).

There have been no publications citing mortality rates among male nurses. In two cohort studies on male physicians, low SMRs were observed for almost all causes of death (*Innos et al, 2000; Carpenter et al, 1997*).

A number of Scandinavian cohort studies have evaluated cancer incidence among nurses using Standardized Incidence Ratios (SIRs). In a Danish study, linkage of the national Occupational Mortality Registry with the Cancer Registry for approximately 27,000 female hospital-based RNs and 7,000 RNs working in other areas revealed significantly elevated SIRs for breast cancer (SIR 1.19) and melanoma (SIR 1.34) (*Rix et al, 1996*). For the BC RN cohort, both breast cancer and malignant melanoma were elevated, with the latter cancer being statistically significant (SIR 1.27). For non-hospital RNs cancer of the breast, liver, corpus uteri and other skin cancers were elevated. Higher SIRs for skin cancers, as found in other studies of nurses (*Sankila et al, 1990; Andersen et al, 1999*) and doctors (*Innos et al, 2000*), have been attributed to exposure to UV light treatment (*Udasin, 2000*). Sunlight exposure during holidays is another suspected aetiological agent. A low lung cancer risk observed in the Danish study (SIR 0.67), was attributed to the general low prevalence of smoking. The SIR for lung cancer incidence was among the lowest of the incidence ratios in the BC cohort of RNs.

A Finnish study linking information on occupation from the census to the Cancer Registry found that RNs had significantly elevated SIRs for all cancers (SIR 1.50), and cancers of the breast (SIR 1.96), corpus uteri (SIR 1.76) and nervous system (SIR 1.56) (*Sankila et al, 1990*). While the incidence of leukaemia, lymphomas and primary liver carcinoma was low among registered nurses, it was high in practical nurses. A U.S. Portland-Vancouver area study found elevated SIRs of both lymphatic and non-lymphatic leukaemia among practical and registered nurses (SIR 3.32 for total leukaemia in female registered nurses,  $p < 0.01$ ) (*Morton et al, 1984*).

An Icelandic retrospective cohort study of female nurses (1920-1979) was consistent with the other Scandinavian studies in showing a statistically significant elevated SIR for breast cancer (*Rix et al, 1996; Sankila et al, 1990; Gunnarsdottir et al, 1995b*). Linkage with the Icelandic Cancer Registry beginning in 1955 (*Gunnarsdottir et al, 1995b*) showed that the most consistent pattern of elevated SIRs was for cancer of the breast, ranging from

1.53 to 3.30, for 20 years and 50 years latency, respectively. Stratification by parity and maternal age at first birth did not appear to explain the excess incidence of breast cancer. The authors concluded that "the possibility cannot be excluded that the nursing occupation constitutes an independent risk factor for breast cancer". The incidence ratio in our BC cohort of RNs was only slightly elevated (SIR 1.05) and just failed to reach statistical significance.

Analysis according to years worked as a nurse indicated statistically significant elevations in breast, lung and rectal cancers and malignant melanoma, based on a 10-year lag. According to the retrospective cohort study on cancer incidence among Icelandic nurses by Gunnardottir *et al* (1995b) nurses employed at least 20 years had an elevated risk of breast cancer (SIR 1.52). We found an increased RR of 1.28 (95% CI 1.04-1.59) for breast cancer with 25 or more years worked as a nurse, based on Poisson regression lagged by 10 years. Other enhanced risks with at least 15 years working as a nurse were for malignant melanoma, lung cancer and rectal cancer. A current hypothesis is that nurses and other health care workers may be prone to cancer and other adverse health effects due to rotating shift and night work. For example, among registered nurses participating in the Nurses' Health Study, in comparison to those who never worked rotating night shifts, the risks of breast cancer and colorectal cancer increased for women working 15 or more years on night shift (Schernhammer *et al*, 2001; Schernhammer *et al*, 2003).

By having yearly updated information on employment, as mandated by the professional association, we were able to examine occupational risk factors that were independently collected and thus avoided recall bias. The few published cohort studies on nurses have generally been limited to evaluating whether nurses as a group are at risk for adverse health outcomes. We identified work areas where registered nurses were potentially at risk for excess mortality and cancer incidence. Because internal comparisons based on cumulative years working in a particular job category were limited to working years from 1974, those years spent prior to 1974 in a specific field of employment could not be accounted for, and therefore each of the exposure categories may be misclassified to some extent (30.9% of the cohort were registered prior to 1974 and others may have been registered in other provinces or countries). Thus, these results must be interpreted cautiously but do suggest research hypotheses for further investigation. Given this

limitation, a number of increased risks were apparent according to job category and estimated exposure. For example, studies on nurses (*Gunnarsdottir et al, 1995a*) and doctors (*Juel et al, 1999*) have shown a significantly increased risk of mortality from suicide among females, an observation not found for the BC RN cohort. However for the field of mental health, there was a significantly elevated risk (RR 3.03) for those working there less than 5 years.

In a 1970 Census Linkage Study on Occupational Cancer, 793 Danish nurses that worked in oncology departments during the period in which nurses had participated in the preparation and administration of antineoplastic drugs, the RR for all cancers was 1.20 (95% CI 0.65-2.01) (*Skov et al, 1992*). The only significantly increased site they found was for leukaemia, with an RR of 10.65 (95% CI 1.29-38.50), but was only based on a few cases. An elevated, but not significant odds ratio of 2.85 (95% CI 0.51-16.02) for leukaemia was observed for physicians handling antineoplastic drugs compared to those unexposed, in a previous case control study by the same authors (*Skov et al, 1990*). We did not find an elevated risk of leukemia for the analysis of potential exposure to antineoplastic agents, nor for employment in cancer centers or oncology. A nested case-control study of 59 cases of breast cancer and 118 randomly selected referents from the Iceland nurses cohort (*Gunnarsdottir et al, 1997*) showed the highest (but not statistically significant) adjusted ORs among those who had ever handled cytotoxic drugs (OR 1.65, 95% CI 0.53-5.17) or who had ever worked in paediatric nursing units (OR 1.47, 95% CI 0.63-3.41). Our analysis of RNs ever working in oncology or at a cancer centre did show a significantly elevated risk (RR 1.84) of breast cancer.

Nurses as an occupational group have not been studied for cancer risks associated with occupational exposure to ionizing radiation. In a Canadian study linking National Dose Registry data of 191,333 workers (from dental, medical, industrial and nuclear power occupations) to incidence data from the Canadian Cancer Database showed significant increased standardized incidence ratios for thyroid cancer and melanoma as well as elevated relative risks for rectal cancer and all types of cancers combined (*Ashmore et al, 1998*). Japanese radiological technologists who were exposed to low doses of ionizing radiation had a statistically significant standard mortality ratio of 1.75 (95% CI: 1.07-2.71) for leukaemia when compared to unexposed professional and technical workers (*Sankila et al, 1990*). However, the results of a linkage study of staff members of radiotherapy

departments in Denmark and the Danish Cancer Registry showed that there was no association between the risk of having a radiogenic type of cancer and exposure to radiation (Lynge, 1994). The only significantly elevated cancer associated with dosimetry measurements for our female cohort of RNs was bladder cancer, but only for those wearing a badge who had levels below the detection limit. On the other hand the survey-based exposure assessment showed relationships between exposure to ionizing radiation sources and breast cancer and leukaemia. It was for lymphatic leukaemia in particular that the highest relative risk of 9.73 was found, but not for the highest exposure category.

According to the 2003 Report on Occupational Exposures in Canada produced by the National Dose Registry (Sont, 2003), Canadian nurses had a higher geometric mean dose of 0.09 mSv (n = 5,351) in 2000 in comparison to the 0.05mSv level for the BC female cohort of RNs. The report showed a peak average dose in 1998, an observation also seen in the BC cohort data. There was little congruence between the survey-based estimation of exposure to ionizing radiation and the actual dosimetry measurements. Some reasons for these differences may be a lack of consistency in the provision of dosimetry badges across departments and hospitals, and misclassification using the survey based group approach. The NDR method gives certainty of exposure, but only for the comparatively few RNs who wore badges and it was assumed that they were worn properly. Of additional concern are the 949 or more RNs who were categorized as having “probable” exposure to ionizing radiation according to the survey, but were not issued a dosimetry badge.

The limitations of our study are related primarily to the following four factors:

- (1) Incomplete work history - There was no work history information available prior to 1974 for those cohort members (30.9% of the total) who had worked as nurses before 1974 because the paper records of their yearly registrations were not accessible. Similarly, those who had worked in jurisdictions outside of BC did not have complete work history information. As a consequence, the exposure job category groupings were misclassified to some extent. Random misclassification would result in bias towards the null (more likely having results not statistically significant).
- (2) Limited exposure ascertainment - The relatively small numbers of field of employment categories were expanded only in the most recent years. For example, information on employment in ORs or PARRs was available only from 1990, which

affected ascertainment of exposure to anaesthetic gases. Because the exposure ascertainment process was primarily retrospective, based on a questionnaire survey of hospitals and health care centres in the province, there was a greater possibility of recall error and misclassification of exposure during earlier periods. Objective measurement data on ionizing radiation were available through the National Dose Registry. However, inconsistent provision of dosimetry badges at the hospitals limited the effectiveness of the analysis.

- (3) Lack of confounder information - Information on other potential lifestyle and socioeconomic risk factors such as smoking status and age at first birth were not available. The prevalence of smoking among nurses and other health care workers tends to be lower than found for the general population. However, delayed childbirth and low parity, which is more common to employed women, has been shown to increase the risk of ovarian and breast cancer.
- (4) Multiple comparisons problem - Another limitation of this epidemiological study arises from the multiple comparisons made, which may result in some excess risks occurring by chance alone. As well, the statistical significance of some associations should be interpreted with caution, particularly where the numbers of cases or deaths were small.

The ideal research design would be to enrol a prospective cohort of nurses with sufficient numbers to investigate relatively rare outcomes. This would allow more accurate and valid measurement of exposures and a variety of outcomes. Such a study would be time-consuming and expensive to undertake but a most worthwhile scientific endeavour.

Further scientific investigation is needed to determine the acute and long-term health effects of exposure to specific hazards in the nursing environment, including ionizing radiation, anaesthetic gases and antineoplastic drugs. The focus of future research programs should include other suspected risk factors, such as night or rotating shift work, as well as identifying hazards that may be unique to certain nursing specialties, such as viral infections transmitted in the maternal newborn and paediatric departments. As well, the interactive effects of exposures on chronic disease outcomes need further exploration. For instance, RNs in the field of oncology had the highest ionizing radiation measurements in addition to exposure to antineoplastic agents. A nested case-control design could be

conducted to investigate hypotheses generated by this study with more thorough evaluation of other influencing factors.

## **7. POLICY AND PREVENTION**

Although the cohort of RNs had relatively low risks of most specific causes of mortality and cancer incidence when calculating standardized ratios through comparison with the general population, there were statistically significant associations of specific causes of mortality or cancer incidence with internal comparisons such as years employed as a nurse, employment in certain specialized fields, and with potential exposure to ionizing radiation. This suggests that there are some hazards present in the nursing workplace that may result in chronic health outcomes of cancer and premature death. Further investigation is needed to substantiate these findings and form the basis of preventive efforts.

General recommendations to minimize work exposures to three specific agents are offered in previous reports to the WCB (*Ward et al, 2005*). More specifically:

- For anaesthetic gases, attention needs to be given to reducing exposures to nitrous oxide, for which a large percentage were found to have exceeded the recommended limits, based on compliance sampling.
- Of concern is the widespread use of portable x-ray equipment often without appropriate precautions, as indicated in our Health Care Facility Survey. We recommend that dosimeter monitoring for ionizing radiation be expanded and more consistently applied across hospitals.
- The number and complexity of available antineoplastic drugs are constantly increasing. New agents to the hospital environment should be rigorously scrutinized for adverse health impacts prior to introduction into the work place, followed by strict adherence to appropriate use of personal protective equipment.

We recommend instituting an education and health surveillance program for nurses and other health care workers that would include exposure monitoring and longitudinal health evaluations for those working in higher risk areas, such as oncology, operating rooms and post-anaesthetic recovery rooms and maternal and paediatric departments.

## **8. DISSEMINATION AND KNOWLEDGE TRANSFER**

A letter to the editor describing the objectives and methods was published in the October 2004 issue of the RNABC magazine, Nursing BC. Eleven registered nurses contacted us for further information following the publication. All were very supportive of the study and shared their personal experiences of dealing with cancer. An invited lecture on the background literature and study proposal, entitled “A study of cancer risks among nurses in BC” was given at the Workers’ Compensation Board of British Columbia in May 2004.

To date the study team has released the following three reports:

- 1) A Retrospective Cohort Study of Cancer Risks among Nurses in British Columbia: Potential Exposure to Ionizing Radiation. Report to the Research Secretariat of the Workers’ Compensation Board of British Columbia, June 2005; 42 pp.
- 2) A Retrospective Cohort Study of Cancer Risks among Nurses in British Columbia: Potential Exposure to Antineoplastic Drugs; Report to the Research Secretariat of the Workers’ Compensation Board of British Columbia,, March 2005; 49 pp.
- 3) A Retrospective Cohort Study of Cancer Risks among Nurses in British Columbia: Potential Exposure to Anaesthetic Gases. Report to the Research Secretariat of the Workers’ Compensation Board of British Columbia, June 2005; 47 pp.

The reports were distributed to the Workers’ Compensation Board of British Columbia, the Registered Nurses Association of British Columbia and the Occupational Health and Safety Agency for Healthcare in British Columbia. The findings of this study have been presented at three scientific conferences involving five members of the study team.

- 1) Dr. Pamela Ratner presented “A survey of antineoplastic drug administration by registered nurses in British Columbia, Canada” at the International Council of Nurses held in Taipei, Taiwan, May 2005.
- 2) Dr. Helen Ward presented “A retrospective cohort study of mortality among registered nurses in British Columbia” at the Canadian Association for Research on Work and Health conference held in Vancouver BC, May 2005.

- 3) Dr. Kay Teschke presented “British Columbia Nurses’ Exposure to Ionizing Radiation: Estimation for a retrospective cohort study of cancer incidence and mortality” at the Canadian Association for Research on Work and Health conference held in Vancouver BC, May 2005.
- 4) Danhong Shu, M.Sc. provided a poster presentation “A retrospective cohort study of cancer incidence among registered nurses in British Columbia” at the Canadian Association for Research on Work and Health conference held in Vancouver BC, May 2005.
- 5) Dr. John Spinelli presented “Cancer risks among registered nurses from British Columbia” at the Canadian Society for Epidemiology and Biostatistics/Society of Epidemiological Research Conference held in Toronto, ON, June 2005.
- 6) Dr. Helen Ward presented “Causes of mortality in a British Columbia cohort of registered nurses” at the Canadian Society for Epidemiology and Biostatistics/Society of Epidemiological Research Conference held in Toronto, ON, June 2005.

Dr. Helen Ward is the first author of a manuscript entitled “Mortality and Cancer Incidence among Registered Nurses in British Columbia” that was submitted to the Scandinavian Journal of Work Environment and Health. Two other manuscripts concerning the ionizing radiation findings and on the internal comparisons according to work category are currently being written respectively by Dr. Kay Teschke of UBC and Maria Lorenzi, MSc, of the BC Cancer Agency.

## **9. ACKNOWLEDGEMENTS**

Funding for our study was provided by the Research Secretariat at the Workers' Compensation Board of British Columbia. We would like to acknowledge the support for this study from the College of Registered Nurses of British Columbia (formerly the Registered Nurses Association of BC), in particular, the Executive Director, Ms. Laurel Brunke. The authors also would like to thank Ms. Lindsay Graham, Ms. Elisa Murru and Ms. Leila Shobab for administering the survey as part of their Simon Fraser University, Kinesiology Cooperative Education program. Doris Zuccarini, the project manager from Statistics Canada, and Christina Poliquin, the data analyst, were very helpful. We are grateful for the cooperation of Dr. Pat Ashmore and Dr. Willem Sont with matters concerning the National Dose Registry as well as Mr. Brian Phillips, Director of Radiation Protection Services at the BC Centre of Disease Control. The letter of support from the Occupational Health and Safety Agency for Healthcare in BC was helpful. We appreciate the time and effort of the many nurses who participated in the survey of BC hospitals and health care centres.



## 10. REFERENCES

- Accorsi A, Barbieri A, Raffi GB, Violante FS. Biomonitoring of exposure to nitrous oxide, sevoflurane, isoflurane and halothane by automated GC/MS headspace urinalysis. *International Archives of Occupational & Environmental Health*. 2001;74(8):541-548.
- Andersen A, Barlow L, Engeland A, Kjaerheim K, Lyng E, Pukkala E. Work-related cancer in the Nordic countries. *Scandinavian Journal of Work, Environment & Health* 1999;25(Suppl 2):1-116.
- Ashmore JP, Krewski D, Zielinski JM, Jiang H, Semenciw R, Band PR. First analysis of mortality and occupational radiation exposure based on the National Dose Registry of Canada. *American Journal of Epidemiology* 1998;148:564-74.
- Baker ES, Connor TH. Monitoring occupational exposure to cancer chemotherapy drugs. *American Journal of Health-System Pharmacy* 1996;53(22):2713-2723.
- Band PR, Le ND, Fang R, Deschamps M, Gallagher RP, Yang P. Identification of occupational cancer risks in British Columbia. A population-based case-control study of 995 incident breast cancer cases by menopausal status, controlling for confounding factors. *Journal of Occupational & Environmental Medicine* 2000;42(3):284-310.
- Bargellini A, Rovesti S, Barbieri A, Vivoli R, Roncaglia R, Righi E, et al. Effects of chronic exposure to anaesthetic gases on some immune parameters. *Science of the Total Environment* 2001 Apr 10;270(1-3):149-156.
- Breslow N, Day N. *Statistical methods in cancer research. The design and analysis of cohort studies*. 1987. Lyon, France.
- Buring JE, Hennekens CH, Mayrent SL, Rosner B, Greenberg ER, Colton T. Health experiences of operating room personnel. *Anesthesiology* 1985;62(3):325-330.
- Carpenter LM, Swerdlow AJ, Fear NT. Mortality of doctors in different specialties: findings from a cohort of 20000 NHS hospital consultants. *Occupational & Environmental Medicine* 1997 Jun;54(6):388-395.
- Chalmers K, Bramadat IJ, Cantin B, Shuttleworth E, Scott-Findlay S. Smoking characteristics of Manitoba nurses. *Canadian Nurse* 2000 Jan;96(1):31-34.
- Colditz GA, Manson JE, Hankinson SE. The Nurses' Health Study: 20-year contribution to the understanding of health among women. *Journal of Women's Health* 1997;6(1):49-62.
- Dalager NA, Kang HK, Thomas TL. Cancer mortality patterns among women who served in the military: the Vietnam experience. *Journal of Occupational & Environmental Medicine*. 1995;37(3):298-305.
- Davis S, Mirick DK, Stevens RG. Night shift work, light at night, and risk of breast cancer. *Journal of the National Cancer Institute* 2001 Oct 17;93(20):1557-1562.

- Dracup K, Bryan-Brown CW. Practicing what we preach. *American Journal of Critical Care* 2002 Nov;11(6):498-500.
- Fair M, Poliquin C, Zuccarini D, Graham D. National Dose Registry Mortality Update: 1950-1994 Mortality Linkage. 2001.
- Finkelstein M, Verma D. Exposure estimation in the presence of nondetectable values: Another look. 2001;62:195-198. *American Industrial Hygiene Association Journal* 2001;62:195-198.
- Gallagher R, Threlfall W, Band P, Spinelli J. Occupational Mortality in British Columbia 1950-1984. 1989.
- Goldberg MS, Carpenter M, Theriault G, Fair M. The accuracy of ascertaining vital status in a historical cohort study of synthetic textiles workers using computerized record linkage to the Canadian Mortality Data Base. *Canadian Journal of Public Health* 1993;84(3):201-204.
- Goto Y, Gallagher J, Fanning N, Wang J, McCusker S, Redmond P, et al. Does chronic occupational exposure to volatile anesthetic agents influence the rate of neutrophil apoptosis? *Canadian Journal of Anaesthesia* 2000 Apr;47(4):350-353.
- Gunnarsdottir H, Aspelund T, Karlsson T, Rafnsson V. Occupational risk factors for breast cancer among nurses. *Journal of Occupational & Environmental Health* 1997;3:254-258.
- Gunnarsdottir H, Rafnsson V. Cancer incidence among Icelandic nurses. *Journal of Occupational & Environmental Medicine* 1995b;37(3):307-312.
- Gunnarsdottir H, Rafnsson V. Mortality among Icelandic nurses. *Scandinavian Journal of Work, Environment & Health*. 1995a;21(1):24-29.
- Habel LA, Stanford JL, Vaughan TL, Rossing MA, Voigt LF, Weiss NS, et al. Occupation and breast cancer risk in middle-aged women. *Journal of Occupational & Environmental Medicine* 1995;37(3):349-356.
- Hansen J. Light at night, shiftwork, and breast cancer risk. *Journal of the National Cancer Institute* 2001 Oct 17;93(20):1513-1515.
- Health Canada. National Dose Registry website. 2002; Available at: <http://www.statcan.ca/english/freepub/82-221-XIE/00604/nonmed/behaviours1.htm>. Accessed June 2005.
- Health Statistics Division, Occupational and Environmental Health Research Section. Summary Report of the Workers Linkage Study: 1950-99 Mortality Update, 1969-99 Cancer Study 2003.
- Hewitt, J. Cancer risks of nurses to assess the carcinogenic potential of antineoplastic drugs. Chicago: University of Illinois; 1992.
- Hobbhahn J, Hoerauf K, Wiesner G, Schrogendorfer K, Taeger K. Waste gas exposure during desflurane and isoflurane anaesthesia. *Acta Anaesthesiologica Scandinavica* 1998;42(7):864-867.
- Hoerauf K, Funk W, Harth M, Hobbhahn J. Occupational exposure to sevoflurane, halothane and nitrous oxide during paediatric anaesthesia. Waste gas exposure during paediatric anaesthesia. *Anaesthesia* 1997;52(3):215-219.

- Hoerauf K, Mayer T, Hobbhahn J. [Occupational exposure to enflurane and laughing gas in operating rooms]. *Zentralblatt für Hygiene und Umweltmedizin* 1996;198(3):265-274.
- Howe GR. Use of computerized record linkage in cohort studies. *Epidemiologic reviews* 1998;20(1):112-121.
- Howe HL. Population-based Cancer Registries in the United States, in Howe HL (Ed.) *Cancer Incidence in North America, 1988-1990*. Springfield, IL: North American Association of Central Cancer Registries, April 1994, pages VI-1 - VI-10.
- Hu FB, Stampfer MJ, Manson JE, Grodstein F, Colditz GA, Speizer FE, et al. Trends in the incidence of coronary heart disease and changes in diet and lifestyle in women.[see comment]. *New England Journal of Medicine* 2000 Aug 24;343(8):530-537.
- Imberti RP, I. Imbrian M, Ghittori S, Cimino F, Mapelli A. Low flow anaesthesia reduces occupational exposure to inhalation anaesthetics. Environmental and biological measurements in operating room personnel. *Acta Anaesthesiologica Scandinavica* 1995;39(5):586-591.
- Infante P, Tsongas T. Anesthetic gases and pregnancy: a review of evidence for an occupational hazard (Chap 24). In: Hemminki K, Sorsa M, Vainio H, editors. *Occupational Hazards and Reproduction* Washington: Hemisphere Publishing Corporation; 1985. p. 287-299.
- Innos K, Rahu M. Epidemiological data sources in Estonia: a survey of registries and databases. *Journal of Epidemiology & Biostatistics*. 2000;5(5):293-302.
- Jaloszynski P, Kujawski M, Wasowicz M, Szulc R, Szyfter K. Genotoxicity of inhalation anesthetics halothane and isoflurane in human lymphocytes studied in vitro using the comet assay. *Mutation Research* 1999 Feb 19;439(2):199-206.
- Juel K, Mosbech J, Hansen ES. Mortality and causes of death among Danish medical doctors 1973-1992. *International Journal of Epidemiology*. 1999;28(3):456-460.
- Katz RM. Causes of death among registered nurses. *Journal of Occupational Medicine* 1983;25(10):760-762.
- Labuhn K, Valanis B, Schoeny R, Loveday K, Vollmer WM. Nurses' and pharmacists' exposure to antineoplastic drugs: findings from industrial hygiene scans and urine mutagenicity tests. *Cancer Nursing* 1998;21(2):79-89.
- Lynge E. Danish Cancer Registry as a resource for occupational research. *Journal of Occupational Medicine* 1994;36:1169-73.
- Morton W, Marjanovic D. Leukemia incidence by occupation in the Portland-Vancouver metropolitan area. *American Journal of Industrial Medicine* 1984;6(3):185-205.
- National Institute for Occupational Safety and Health (NIOSH). *Life Table Analysis System for the PC*. Cincinnati, OH: US Department of Health and Human Services; 2000.
- Nikki P, Pfaffli P, Ahlman K, Ralli R. Chronic exposure to anaesthetic gases in the operating theatre and recovery room. *Annals of Clinical Research* 1972;4(5):266-272.

Norppa H, Sorsa M, Vainio H, Grohn P, Heinonen E, Holsti L, et al. Increased sister chromatid exchange frequencies in lymphocytes of nurses handling cytostatic drugs. *Scandinavian Journal of Work, Environment & Health* 1980;6(4):299-301.

Omenn GS, Morris SL. Occupational hazards to health care workers: report of a conference. *American Journal of Industrial Medicine* 1984;6(2):129-137.

Peric M, Vranes Z, Marusic M. Immunological disturbances in anaesthetic personnel chronically exposed to high occupational concentrations of nitrous oxide and halothane. *Anaesthesia* 1991 Jul;46(7):531-537.

Petralia SA, Dosemeci M, Adams EE, Zahm SH. Cancer mortality among women employed in health care occupations in 24 U.S. states, 1984-1993. *American Journal of Industrial Medicine* 1999a;36(1):159-165.

Petralia SA, Vena JE, Freudenheim JL, Michalek A, Goldberg MS, Blair A, et al. Risk of premenopausal breast cancer and patterns of established breast cancer risk factors among teachers and nurses. *American Journal of Industrial Medicine* 1999b;35(2):137-141.

Prado C, Tortosa JA, Ibarra I, Luna A, Periago JF. Biological monitoring of occupational exposure to isoflurane by measurement of isoflurane exhaled breath. *Journal of Applied Toxicology* 1997;17(3):179-183.

Rix BA, Lynge E. Cancer incidence in Danish health care workers. *Scandinavian Journal of Social Medicine* 1996;24(2):114-120.

RNABC. *RNABC News*. 1986;18:32.

Ron E. Ionizing radiation and cancer risk: evidence from epidemiology. *Radiation Research* 1998 Nov;150(5 Suppl):S30-41.

Rothman KJ, Greenland S. *Modern Epidemiology*. : Lippincott Williams & Wilkins; 1998.

Sankila R, Karjalainen S, Laara E, Pukkala E, Teppo L. Cancer risk among health care personnel in Finland, 1971-1980. *Scandinavian Journal of Work, Environment & Health* 1990;16(4):252-257.

Sass-Kortsak AM, Purdham JT, Bozek PR, Murphy JH. Exposure of hospital operating room personnel to potentially harmful environmental agents. *American Industrial Hygiene Association Journal* 1992;53(3):203-209.

Schernhammer ES, Laden F, Speizer FE, Willett WC, Hunter DJ, Kawachi I, et al. Rotating night shifts and risk of breast cancer in women participating in the nurses' health study.[see comment]. *Journal of the National Cancer Institute* 2001 Oct 17;93(20):1563-1568.

Schernhammer ES, Laden F, Speizer FE, Willett WC, Hunter DJ, Kawachi I, et al. Night-shift work and risk of colorectal cancer in the nurses' health study. *Journal of the National Cancer Institute* 2003 Jun 4;95(11):825-828.

Sessink PJ, Bos RP. Drugs hazardous to healthcare workers. Evaluation of methods for monitoring occupational exposure to cytostatic drugs. *Drug Safety* 1999;20(4):347-359.

Sessler DI, Badgwell JM. Exposure of postoperative nurses to exhaled anesthetic gases. *Anesthesia & Analgesia* 1998;87(5):1083-1088.

Skov T, Lynge E, Maarup B, Olsen J, Rorth M, Winthereik H. Risks for physicians handling antineoplastic drugs. *Lancet* 1990;336(8728):1446.

Skov T, Maarup B, Olsen J, Rorth M, Winthereik H, Lynge E. Leukaemia and reproductive outcome among nurses handling antineoplastic drugs. *British Journal of Industrial Medicine* 1992;49(12):855-861.

Sont WN (National Dose Registry). 2003 Report on Occupational Exposures in Canada. Ottawa: National Dose Registry; 2003.

Sont WN, Zielinski JM, Ashmore JP, Jiang H, Krewski D, Fair ME, et al. First analysis of cancer incidence and occupational radiation exposure based on the National Dose Registry of Canada. *Am J Epidemiol* 2001 Feb 15;153(4):309-318.

Statistics Canada. Canadian Cancer Registry. 2005; Available at: <http://www.statcan.ca/cgi-bin/imdb/p2SV.pl?Function=getSurvey&SDDS=3207&lang=en&db=IMDB&dbg=f&adm=8&dis=2>. Accessed August 12, 2005, 2005a.

Statistics Canada. Causes of death 1996. 1997. Available at: <http://www40.statcan.ca/101/cst01/>. Accessed June, 2005.

Statistics Canada. Smoking Status by sex, Canada, provinces, territories, health regions and peer groups. Available at: <http://www.statcan.ca/english/freepub/82-221-XIE/00604/nonmed/behaviours1.htm>. Accessed October, 2005b.

Steenland K, Spaeth S, Cassinelli R, 2nd, Laber P, Chang L, Koch K. NIOSH life table program for personal computers. *American Journal of Industrial Medicine* 1998 Nov;34(5):517-518.

The R Foundation for Statistical Computing Version 2.0.0. ISBN 3-900051-07-0. 2004-10-04

Threlfall WJ, Gallagher RP, Spinelli JJ, Band PR. Reproductive variables as possible confounders in occupational studies of breast and ovarian cancer in females. *Journal of Occupational Medicine* 1985;27(6):448-450.

Trinkoff AM, Storr CL. Substance use among nurses: differences between specialties. *American Journal of Public Health* 1998 Apr;88(4):581-585.

Udasin IG. Health care workers. *Primary Care; Clinics in Office Practice* 2000 Dec;27(4):1079-1102.

Ward HD, Teschke K, Ratner PA, Le N, Spinelli J, Gallagher R. A Retrospective Cohort Study of Cancer Risks Among Nurses in British Columbia. Potential Exposure to: Anaesthetic Gases, Antineoplastic Drugs, Ionizing Radiation. Report to the Research Secretariat of the Workers' Compensation Board of British Columbia. 2005.

## APPENDIX I: JOB TITLE INFORMATION

### I a. Job title information for registered nurses, (1999 Registration Renewal Form)

#### **FIELD OF EMPLOYMENT**

##### ***Direct Patient Care:***

Medical/ Surgical  
Critical Care, e.g. ICU, CCU  
Oncology  
Operating Room (OR)  
Post-Anesthetic recovery room  
(PARR)  
Ambulatory care  
Emergency care  
Maternal/ Newborn  
Psychiatric/ Mental health  
Paediatrics  
Rehabilitation  
Geriatrics/ Long term care  
Occupational health  
Several clinical areas  
Community health  
Home care  
Other (specify)

##### **Administration:**

Nursing education administration  
Nursing services administration  
Other administration

##### **Education:**

Teaching - Students  
Teaching - Employees  
Teaching - Patients/ Clients  
Other education

##### **Research:**

Nursing research only  
Other research (specify)

#### **PLACE OF EMPLOYMENT**

Hospital  
Rehabilitation/ Convalescent Centre  
Extended Care  
Long term care/ Nursing home  
Mental health centre  
Home care Agency  
Community health agency/Health centre  
Business/Industry/ Occupational health  
Physician's office/ Family practice unit  
Educational Institution  
Self-Employed / Private practice  
Private nursing agency/ private duty  
Association/ Government  
Nursing stations/ Outpost/ Nurse clinic  
Other (specify)

#### **POSITION OF EMPLOYMENT**

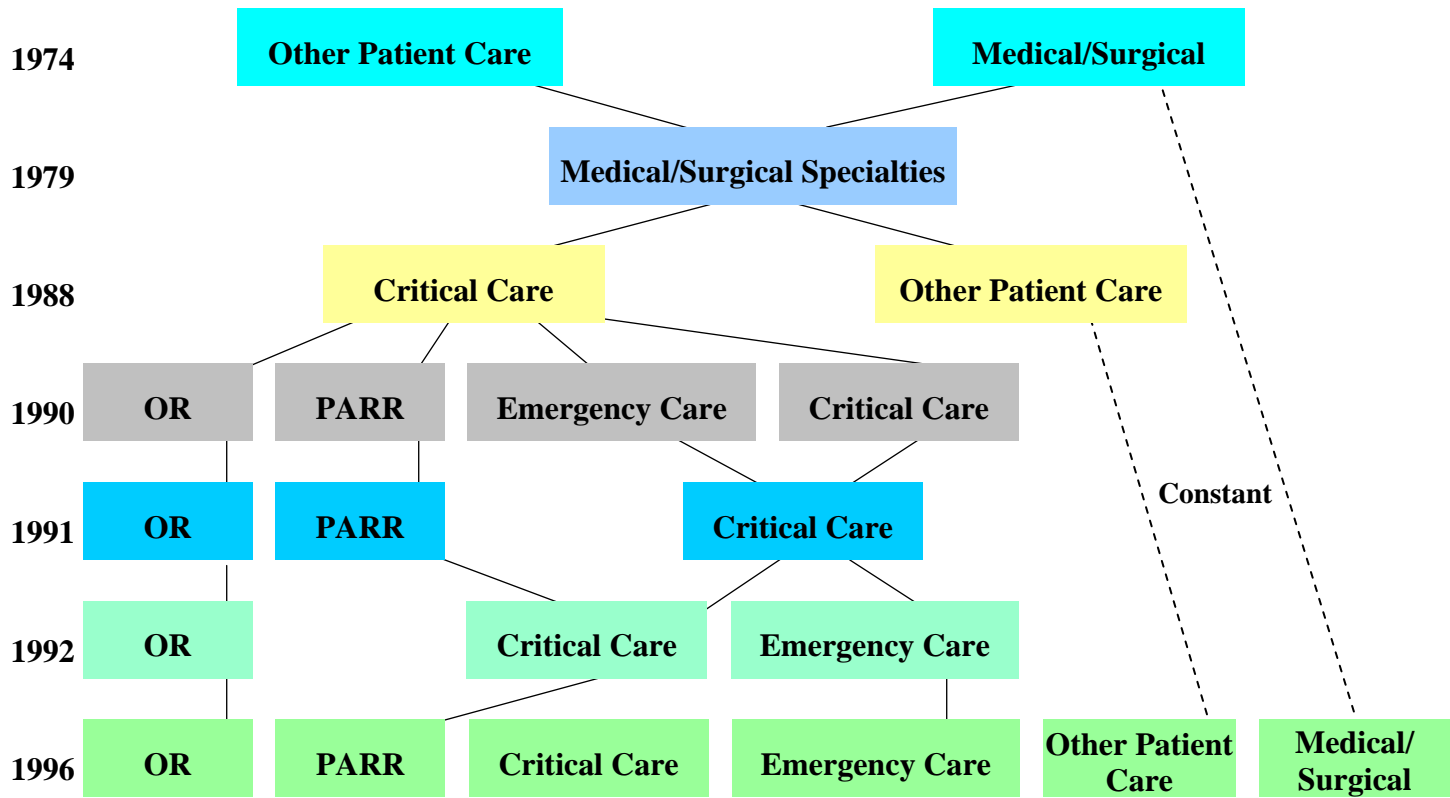
Chief nursing officer/ Director  
Assistant/ Associate director  
Supervisor/ coordinator  
Clinical nurse specialist  
Head nurse/ unit manager  
Staff nurse/ Home care/ Community  
nurse  
Office/ Occupational/ Industrial nurse  
Instructor/ Professor  
Consultant/ Counsellor  
Researcher  
Other (specify)

#### **EMPLOYMENT STATUS**

##### ***Employed in Nursing:***

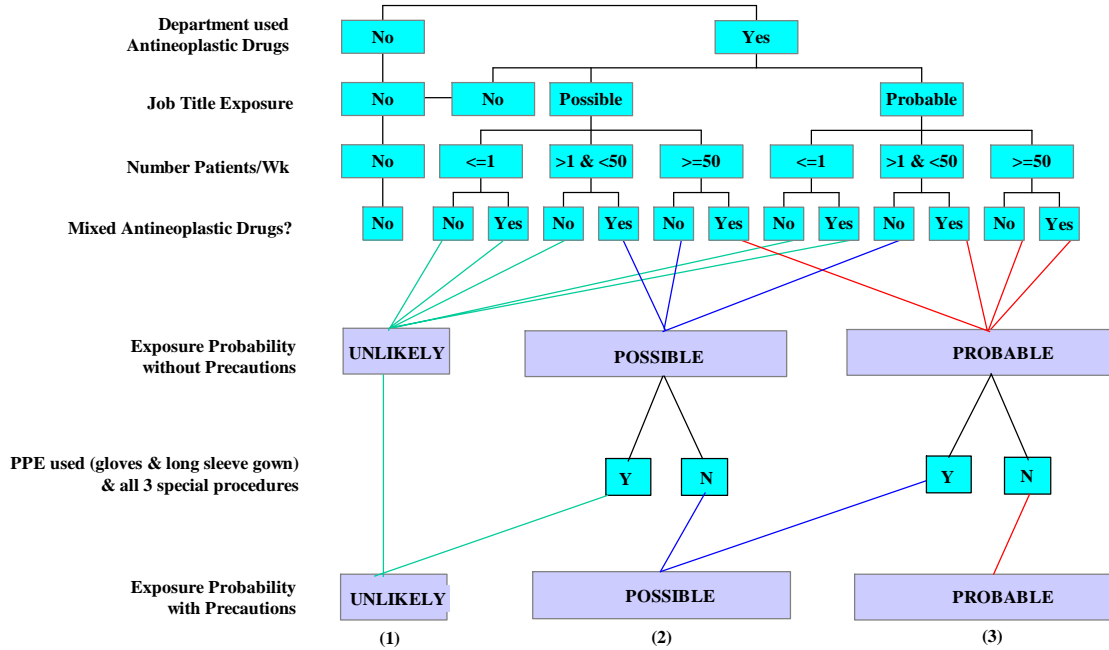
Regular basis  
Casual/Seasonal  
Employed – Not in Nursing  
Not Employed

**I b. Transition of Field of Employment Categories (Medical/Surgical Specialties) during Cohort Period**

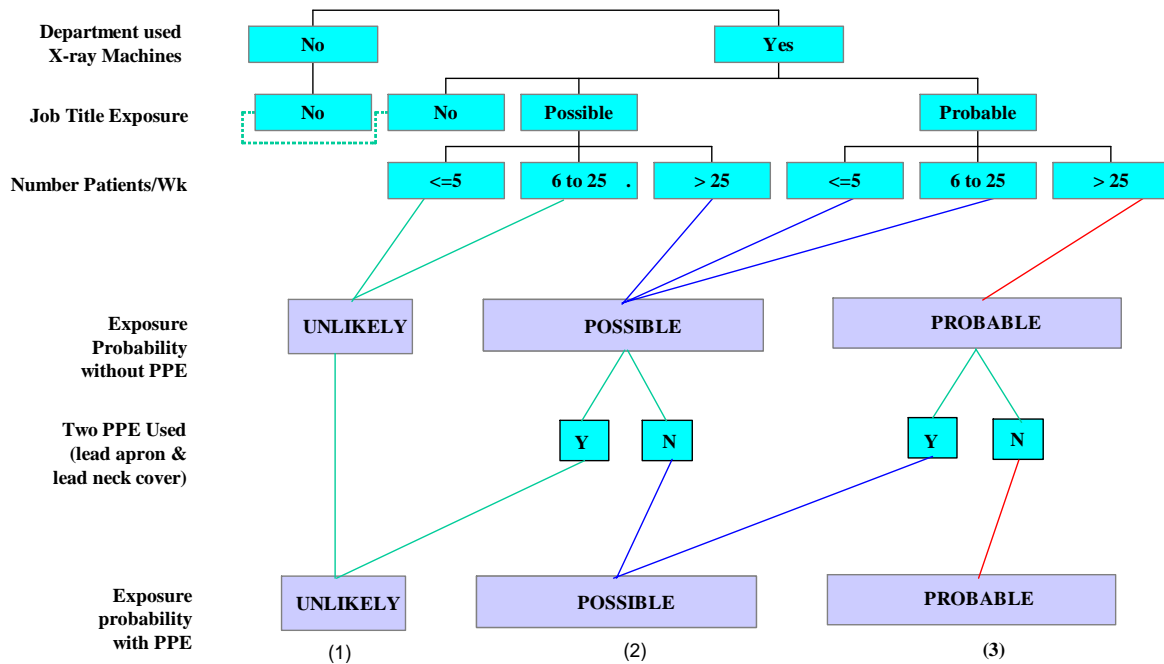


## APPENDIX II: EXPOSURE ALGORITHMS

### II a. Algorithm of Probability for Antineoplastic Drug Exposure



### II b. Algorithm of Probability for Ionizing Radiation Exposure



### APPENDIX III: ICD 9 CODES

<b>Disease</b>	<b>Code(s)</b>
<b>Infective &amp; Parasitic Diseases</b>	
Other Infective & Parasitic Diseases	001-113
<b>Cancer: All Buccal Cavity and Pharynx</b>	
Lip	140
Tongue	141
Salivary Gland	142
Mouth	143-145
Oropharynx	146
Nasopharynx	147
<b>Cancer: All Digestive Cancers</b>	
Esophagus	150
Stomach	151
Small Intestine	152
Large Intestine except Rectum	153, 159
Rectum & Rectosigmoid Junction	154
Liver	155.0-155.1
Gallbladder	156
Pancreas	157
Peritonuem	158
<b>Cancer: All Respiratory Cancers</b>	
Nose/Sinuses	160
Lung (includes Trachea & Bronchus)	162
Pleura	163
Other Respiratory	164.2-164.3, 164.8-165
<b>Cancer: Female Genital</b>	
Uterus including Cervix	179-182
Other Female Genital	184
<b>Cancer: Male Genital</b>	
Prostate	185
<b>Cancer: Urinary</b>	
Kidney	189.0-189.2
Bladder & Other Urinary	188, 189.3-189.9
<b>Cancer: Other Neoplasms</b>	
Bone	170

Connective Tissue	164.1, 171
Malignant Melanoma	172
Other Skin	173
Breast (Female)	174
Eye	190
Brain & Nervous System	191-192
Thyroid	193
Other Endocrine Glands	164.0, 194
Ill-defined Cancer	195
<b>Cancer: Lymphatic &amp; Hematopoietic Neoplasms</b>	
Non-Hodgkin's Lymphomas	200, 202
Hodgkin's Disease	201
Multiple Myeloma	203
Lymphatic Leukemia	204
Myeloid Leukemia	205
Monocytic Leukemia	206
Other & Unspecified Leukemia	207.0, 207.2, 207.8, 208
<b>Cancer: Benign &amp; Unspecified Neoplasms</b>	
Benign Neoplasms	210-229
Neoplasm of Unspecified Nature	235-239
<b>Endocrine /Nutritional /Metabolic Diseases</b>	
Diabetes Mellitus	250
Other Endocrine/Metabolic	240-249, 251-279
<b>Blood Diseases</b>	
<b>Mental Disorders</b>	
<b>Nervous System/Sense Organ Disease</b>	
<b>Circulatory Diseases</b>	
Rheumatic Heart Disease including Fever	390-398, 424.0, 424.1, 424.3
Hypertensive Disease	401-405
Ischemic Heart Disease	411-414, 429.2
Acute Myocardial Infarction	410
Cerebrovascular Disease	430-438
Disease of Arteries, Arterioles & Capillaries	440-448
<b>Circulatory Diseases continued</b>	
Disease of Veins, Lymphatics & Other Disease	415.1, 451-459
Other Circulatory Disease	399-400, 406-409, 415.0, 415.2-423, 424.2, 424.4-429.1, 429.3-429.9, 439, 449-450

<b>Respiratory Diseases</b>	
Pneumonia	480-486
Chronic Obstructive Pulmonary Disease	490-492, 496
Asthma	493
Other Respiratory Diseases	467-469, 479, 488-489, 494, 497-499, 506-519
<b>Digestive Diseases</b>	
Ulcers	531-534
Cirrhosis of Liver	571
Other Digestive Diseases	520-530, 535-570, 572-579
<b>Genitourinary Diseases</b>	
Kidney Diseases	580-593
Other Genitourinary Disease	594-629
<b>Musculoskeletal Diseases</b>	
<b>710-739</b>	
<b>Symptoms/Ill-Defined</b>	
<b>780-799</b>	
<b>Accidents/ Poisoning/ Violence</b>	
Motor Vehicle Traffic Accident	810-813, 815-819
MVTA Involving Pedestrian	814
Accidental Drowning	910, 830, 832
Accidental Poisoning	850-869
Accidental Falls	880-888, 929.3
Suicide	950-959
Homicide	960-969
Other Accidents or Violence	800-809, 820-829, 831, 833-849, 870-879, 889-909, 911-929.2, 929.5-949, 970-999.0
All Other Causes of Death	999.9

## APPENDIX IV: DOSIMETRY RESULTS

### IV a. Body Doses (mSv) by Year for Dosimetry Measurements (5 Year Intervals)

Year	Cumulative Yearly Doses	Mean	SD	Geometric Mean (mSv)	Maximum (mSv)
1955	4	8.49	4.60	6.86	11.70
1960	21	3.23	4.38	0.44	13.43
1965	37	3.11	4.99	0.90	21.72
1970	169	0.61	1.80	0.05	10.85
1975	422	0.31	1.19	0.03	15.00
1980	525	0.31	0.87	0.04	10.30
1985	657	0.19	0.59	0.03	9.00
1990	726	0.08	0.26	0.02	3.30
1995	430	0.38	1.47	0.03	14.94
2000	236	0.75	2.14	0.05	18.70
Total (1952-2003)	16,246	0.36	1.66	0.03	66.00
Total (1974-2000)	13,973	0.26	1.41	0.03	66.00

#### IV b. Dosimetry Measurements by Place of Employment

Place of Employment	N	Mean (mSv)	SD (mSv)	Geometric Mean (mSv)	Maximum (mSv)
Rehabilitation/Convalescent Centre	5	0.76	1.03	0.10	2.05
Public Health Agency	12	0.34	1.14	0.02	3.95
Private Nursing Agency/Private Duty	6	0.31	0.73	0.03	1.80
Other	164	0.31	1.18	0.03	10.30
Hospital	6004	0.29	1.38	0.03	66.00
Mental Health Centre	9	0.28	0.40	0.06	0.90
Other hospital	21	0.22	0.79	0.03	3.65
Educational Institution	43	0.20	0.38	0.04	1.30
Unknown	60	0.17	0.85	0.02	6.40
Nursing Station/Outpost/Clinic	65	0.14	0.41	0.03	2.80
Long Term Care	56	0.12	0.39	0.02	2.50
Association/Government	75	0.11	0.38	0.02	3.01
Community Health	225	0.09	0.28	0.02	2.40
Extended Care	10	0.05	0.09	0.02	0.30
Business/Industry/Occupational Health	26	0.04	0.08	0.02	0.30
Physician's Office/Family Practice unit	231	0.04	0.18	0.02	2.20
Home Care Agency	12	0.04	0.08	0.02	0.30
Self Employed	4	0.01	0.00	0.01	0.01
Total	7028	0.27	1.30	0.03	66.00

#### IV c. Dosimetry Measurements by Field of Employment

Field of employment	N	Mean (mSv)	SD (mSv)	Geometric Mean (mSv)	Maximum (mSv)
Oncology	21	3.44	14.35	0.04	66.00
Other <sup>1</sup>	1089	0.68	1.81	0.05	16.50
Unknown	292	0.36	1.31	0.04	17.60
Research	72	0.32	0.60	0.06	2.80
Ambulatory Care	142	0.28	0.82	0.03	5.40
Psychiatry/Mental Health	13	0.27	0.52	0.04	1.60
Several Clinical Areas	641	0.26	1.12	0.03	16.10
Teaching	63	0.26	0.89	0.03	5.10
Critical Care	1320	0.23	0.98	0.03	18.90
Geriatrics/Gerontology	58	0.22	1.26	0.02	9.60
Home Care	6	0.21	0.48	0.03	1.20
Emergency Care	67	0.17	0.65	0.03	5.00
Administration	160	0.15	0.80	0.03	9.60
Medical/Surgical	945	0.14	0.48	0.03	5.20
Operating Room	372	0.13	0.70	0.02	10.20
Medical/Surgical Specialties	1434	0.11	0.49	0.02	8.40
Occupational Health	25	0.09	0.13	0.03	0.40
Community Health	127	0.09	0.27	0.02	2.40
Paediatrics	91	0.09	0.18	0.03	0.90
Post-Anaesthesia Recovery Room	31	0.06	0.21	0.02	1.20
Maternal Newborn	57	0.03	0.07	0.02	0.40
Rehabilitation	2	0.01	0.00	0.01	0.01
Total	7028	0.27	1.30	0.03	66.00

<sup>1</sup> Includes Other Patient Care and Neurosciences.

#### IV d. Dosimetry Measurements by Position of Employment

Position of employment	N	Mean (mSv)	SD (mSv)	Geometric Mean (mSv)	Maximum (mSv)
Other/Not listed	650	0.66	2.96	0.05	66.00
Clinical nurse specialist	92	0.40	0.95	0.05	5.30
Head nurse	528	0.40	1.52	0.04	16.50
Consultant/Counsellor	8	0.30	0.45	0.06	1.00
Instructor/Professor	44	0.28	0.93	0.03	5.10
Unknown	298	0.24	1.25	0.03	17.60
Researcher	18	0.23	0.69	0.02	2.80
Staff/Home care/Community nurse	5,219	0.21	0.89	0.03	18.90
Manager/Supervisor	106	0.17	0.94	0.03	9.60
Director/Assistant/Associate	44	0.07	0.14	0.03	0.80
Chief nursing/Executive officer	13	0.07	0.14	0.02	0.50
Office/Occupational nurse	8	0.01	0.00	0.01	0.01
Total	7,028	0.27	1.30	0.03	66.00

#### IV e. Comparison of Methods: BC Hospital Survey vs. NDR Data

		BC Hospitals Survey Exposure Levels			
Year	NDR Exposure Levels	<i>None</i>	<i>Unlikely</i>	<i>Possible</i>	<i>Probable</i>
1977	No Badge	13,935 (91.2%)	615 (4.0%)	351 (2.3%)	244 (1.6%)
	Badge:<DL*	101 (0.7%)	4 (0.03%)	2 (0.01%)	4 (0.03%)
	Badge: >DL	26 (0.2%)	0 (0.0%)	1 (0.01%)	0 (0.0%)
1987	No Badge	20,222 (86.7%)	957 (4.1%)	1,216 (5.2%)	571 (2.5%)
	Badge:<DL	151 (0.7%)	25 (0.1%)	28 (0.1%)	68 (0.3%)
	Badge: >DL	43 (0.2%)	17 (0.1%)	7 (0.03%)	12 (0.1%)
1997	No Badge	23,665 (83.5%)	1,851 (6.5%)	1,677 (5.9%)	949 (3.4%)
	Badge:<DL	86 (0.3%)	30 (0.1%)	10 (0.04%)	11 (0.04%)
	Badge: >DL	37 (0.1%)	3 (0.01%)	12 (0.04%)	3 (0.01%)

\*DL = Detection limit. Note that individuals may be included in more than one year.

All rights reserved. The Workers' Compensation Board of B.C. encourages the copying, reproduction, and distribution of this document to promote health and safety in the workplace, provided that the Workers' Compensation Board of B.C. is acknowledged. However, no part of this publication may be copied, reproduced, or distributed for profit or other commercial enterprise or may be incorporated into any other publication without written permission of the Workers' Compensation Board of B.C.

Additional copies of this publication may be obtained by contacting:

Research Secretariat  
6951 Westminster Highway  
Richmond, B.C. V7C 1C6  
Phone (604) 244-6300 / Fax (604) 244-6295  
Email: [resquery@worksafebc.com](mailto:resquery@worksafebc.com)