

REVIEW

Cancer in veterinarians

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Abstract

Objectives—Veterinarians come into contact with several potentially carcinogenic exposures in the course of their occupation. These exposures include radiation, anaesthetic gases, pesticides (particularly insecticides), and zoonotic organisms. This review aims to summarise what is known about the carcinogenic risks in this profession.

Methods—The levels of exposure to potential carcinogens in the veterinary profession are examined and evidence is reviewed for carcinogenesis of these substances in humans at doses similar to those experienced by veterinarians. The few published studies of cancer in veterinarians are also summarised.

Results—Veterinarians have considerable potential for exposure to several known and potential carcinogens. Risks may be posed by work in clinics with poorly maintained x ray equipment, by use of insecticides, and from contact with carcinogenic zoonotic organisms. The few studies available suggest that veterinarians have increased mortality from lymphohaematopoietic cancers, melanoma, and possibly colon cancer.

Conclusions—The exposures examined in this review are not unique to the veterinary profession, and, as a consequence, information gathered on the carcinogenic risks of these exposures has implications for many other occupations such as veterinary nurses, animal handlers, and some farmers, as well as dentists, radiographers, and anaesthetists.

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Veterinarians come into contact with several potentially carcinogenic exposures in the course of their occupation including radiation, anaesthetic gases, pesticides (particularly insecticides), and zoonotic organisms. However, very little is known about the carcinogenic risks in this occupation.

In this review, the levels of exposure to potential carcinogens in the veterinary profession are examined and evidence is reviewed for carcinogenesis of these substances. Although evidence on the carcinogenicity for some of these exposures in veterinary practitioners is

scant, there are some publications on the carcinogenic effects of similar exposures in other professions. The few published studies of cancer in veterinarians are also summarised.

Exposures in veterinary medicine*X RAYS**Exposure levels*

It is thought that most practicing veterinarians use radiographic equipment. In a postal survey of all women graduating from United States colleges of veterinary medicine in the 1970s, 64% of subjects stated that they had been exposed to radiation during pregnancy.¹ This survey achieved an impressive response of 90% with a sample size of 2427.

In another postal survey of all women who had graduated from the University of California with a veterinary medicine degree, 82% had potential exposure to ionising radiation.² Again the response was high (86%) and the sample size quite large (n=457). This survey may be more representative of usual exposures than the other, as the exposures were not confined to those experienced during pregnancy. Exposure to x rays was most common in small animal practice (90%) as opposed to large animal practice (77%) and other practice (52%). Of those who reported taking x ray films, 43% took more than five a week, and 22% took more than 10 a week.

The annual occupational permissible dose according to the International Commission on Radiological Protection is 20 mSv. A study was conducted of women veterinarians living in three states who had graduated from a United States veterinary school during the 1970s.³ One hundred and eighteen subjects (91% of those eligible) agreed to wear radiation dosimeters for 3 months and results were available for 86% of those. Exposures >1.5 mSv/month were recorded for 20 (9.2%) of the 271 person-months monitored. These doses are well below the maximal permissible dose for occupational exposure; however, it is possible that the veterinarians changed their behaviour as they knew they were being monitored.

In the United Kingdom, the National Radiation Protection Board (NRPB) surveyed 50 veterinary practices in 1993.⁴ In each practice, the “person normally standing closest to the x ray machine” wore body and extremity dosimeters for 1 month. Doses were only recorded in three of the 50 practices and these were all <0.3 mSv.

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There are several factors specific to veterinary practice which may affect the radiation dose, including the need to restrain the animal during procedures, poorly maintained equipment, and lack of training in radiation safety. In the Californian survey,² 76% of respondents reported restraining animals at least once a month during *x* ray procedures. The NRPB report stated that "manual restraint of animals would appear to be still practised perhaps more frequently than is desirable or necessary" with many practices restraining more than 50% of animals undergoing radiography.⁴

Studies before 1980 found high prevalences of poorly shielded radiographic equipment and protection practices in veterinary surgeries.⁵⁻⁷ However, even in 1987 a survey of 29 randomly selected veterinary practices with radiographic equipment in Ohio, USA (with 83% response) found that not all practices complied with safety guidelines.⁸ This study used only practices which had their radiography machines registered with the Department of Health, and we are not told whether this would include all practices with radiology facilities. Collimators, which narrow the *x* ray beam, were not present in 14% of practices. Lead aprons and gloves were available in most practices, but were not often tested for leaks. Film badges were worn in about half the practices, with some practices sharing the badges between several people. Lead lining was present in only two practices, with a lead lined shield available in a further five practices (total=24%). The dosimetry study of United States female veterinarians already described³ found similar results with most subjects wearing lead aprons and gloves, but only 38% of practices having a lead shield. The NRPB study found that most *x* ray machines were old (modal age 20 years) and many were poorly maintained; however, the *x* ray rooms seemed to provide adequate screening in most cases.⁴ The NRPB developed a "vet pack" to help veterinarians meet standards for *x* ray equipment and procedures; however, this has recently been discontinued due to lack of interest from the veterinary profession.

There are several papers describing the exposure of radiologists and surgeons to radiation. Monthly doses of physicians in emergency departments, who might be expected to only have occasional exposure to *x* rays, have been measured at 0.0012 mSv.⁹ Radiologists working with diagnostic radiology have been reported as receiving 0.1–0.5 mSv monthly and those working in therapeutic radiology may have slightly higher doses.^{10, 11} Orthopaedic surgeons who use fluoroscopy may have quite high exposures to the hands although in 80% of procedures the dose is <0.1 mSv.¹² Thus it seems that veterinarians currently have lower exposures than radiologists and surgeons.

Evidence for carcinogenicity at exposure levels similar to veterinarians

The carcinogenic effects of ionising radiation have been recognised for many years, particularly for skin cancer, thyroid cancer, and leukaemia.¹⁵

Cohorts of radiologists have been examined in the United States¹⁴ and the United Kingdom,¹⁵ with complete population enumeration and nearly complete follow up for mortality but no data on cancer incidence. Both studies found that radiologists who started practice before 1920 had increased death rates from skin cancer and leukaemia compared with other physicians¹⁴ or to the English population.¹⁵ In more recent cohorts there have been no significant differences between death rates for any cancer in radiologists compared with other doctors.¹⁶ Physicians may be expected to have their cancers diagnosed earlier or perhaps treated better, and this bias could be assessed by examining incidence of cancer.

A case-control study found that women dentists and dental nurses had 13 times the risk of thyroid cancer compared with those not in these two occupations.¹⁷ However, this result was based on only seven exposed cases and one exposed control and 95% confidence intervals (95% CI) were extremely wide (95% CI 2.1 to 389). Record linkage studies have suggested that dental personnel have an increased risk of melanoma¹⁸⁻²⁰ as well as raised risk of colorectal cancer,¹⁸ although both these cancers are associated with higher socioeconomic status and not necessarily with *x* rays or other occupational substances.

ANAESTHETICS

Exposure levels

Almost all practicing veterinarians perform surgery and much of this involves general anaesthesia. The anaesthetic equipment used in veterinary surgery is similar to that used in human hospitals. Animals are usually initially anaesthetised with an injectable anaesthetic, then maintained on inhalational anaesthetics.²¹ Both rebreathing and non-rebreathing systems are used and the main substances used are halogenated anaesthetics and nitrous oxide.

In the studies of American women veterinarians already described, exposure to anaesthetic gas was reported by between 63% and 83% of female veterinarians.^{1, 2} A further study of private veterinary practices in Colorado, USA, found that 81% of practices used inhalation anaesthetics, although use varied with type of practice: 90% of small animal practices and 59% of large animal practices.²¹

The National Institute for Occupational Safety and Health (NIOSH) recommends that exposures to halogenated anaesthetics be maintained below 2.0 ppm with a time weighted average (TWA) of 50 ppm.^{21, 22} Halothane concentrations in veterinary surgeries seem to exceed the maximal limit in 30%–50% of measurements.²²⁻²⁴ Personal monitoring ranges from 0.7 ppm to about 20 ppm^{22, 24-27} although measurements of up to 105 ppm have been recorded.²⁷ Calculated 8 hour TWAs tend to be lower at around 1.2 ppm.²³ It has also been shown that concentrations of halothane in recovery rooms may be above the NIOSH recommendations for up to 2 hours as the patient is recovering from the operation.²⁸

For nitrous oxide, NIOSH recommends exposures be maintained at <25 ppm^{21 22} with a TWA of 50 ppm.²⁶ This concentration is exceeded in most (75%) surgeries.²² Personal exposure has been measured at between 6 ppm and 270 ppm.^{22 25} The geometric mean exposure to nitrous oxide of 23 United Kingdom veterinarians was 75 ppm and when calculated as an 8 hour TWA this was 27 ppm.²³

Use of scavenging systems reduces anaesthetic exposures considerably.^{21 23-25 29} However, waste anaesthetic gas scavenging is not used in many veterinary practices. In the United States, use was reported in only about 10% of practices in surveys done during the 1980s.^{24 25} In more recent studies in the United Kingdom 50% of surveyed practices had scavengers²³ whereas in Canada all 10 clinics surveyed had scavengers.²⁶ However, most equipment included passive rather than active systems.^{23 26}

Although measured values of anaesthetics are higher than recommended for human hospitals, veterinarians spend less time than human anaesthetists with anaesthetics. Most small animal veterinarians spend 5–20 hours a week performing surgery and in the recovery room.^{2 21 26} On days when veterinarians are in the operating room, the average daily time spent using anaesthetics is 1.8 hours.²⁴ In comparison, the mean time spent weekly in theatres by human anaesthetists as shown by a postal survey was 33.2 hours and by surgeons it was 12.8 hours.³⁰

Evidence for carcinogenicity at exposure levels similar to veterinarians

The main concern with anaesthetics is for their reproductive rather than carcinogenic effects. The evidence for carcinogenicity of volatile anaesthetics was reviewed by the International Agency for Research in Cancer in 1987.³¹ There were some reports of increases in lymphohaematopoietic and pancreatic cancers but these were not consistent over the few studies reported. It was concluded that there was not enough information available to classify volatile anaesthetics as to their carcinogenicity. Two more recent cohort studies which included registered British anaesthetists found no significant increases in lymphohaematopoietic or pancreatic cancers.^{16 32} An increased risk of dying from melanoma (relative risk (RR) 3.33, 95% CI 1.22 to 7.25) was found in one study.¹⁶ Several postal questionnaire studies have not found increased reported cancer among anaesthetists in North America and the United Kingdom, although site specific rates were not reported, and responses were around 75%.^{30 33} A survey of 44 000 dentists and chairside assistants with a 70% response, found very small non-significant increases in risk of self reported incident cancer (any site) for those with heavy exposure to anaesthetics compared with those with no exposure.³⁴

INSECTICIDES

Exposure concentrations

Practising veterinarians are often exposed to insecticides, primarily through cutaneous ex-

posure to flea dips and other pet products.² In the two surveys of women veterinarians already described, exposure to pesticides in the past year was reported by 52% of women veterinarians² and exposure during pregnancy was reported by 84%.¹ Of those exposed in the previous year, 49% stated that they had been exposed to pyrethrins, 36% mentioned carbamates, and 2% mentioned captan.²

There are few publications on quantitative exposures to insecticides in the veterinary profession. In large animal practice, veterinarians may treat cattle with "pour on" organophosphate insecticides. A survey of 18 volunteer veterinarians known to be performing this treatment found that some had experienced mild symptoms of poisoning, but there was no consistent and progressive depression of blood cholinesterase activities.³⁵ The finding of acute effects of organophosphate insecticides does not necessarily mean that doses are sufficient for any chronic effects to occur. It was also acknowledged in this paper that the types and quantities of insecticides used were not necessarily typical of bovine veterinary practice.

Animal groomers and pet handlers are also exposed to flea control products which are used by veterinarians. A telephone survey of nearly 700 pet handlers, 40% of whom were veterinary clinic workers, was conducted in California with a 77% response.³⁶ Handlers who applied flea control products were significantly more likely to report symptoms such as skin rash, tearing, unusual tiredness, burning of the eyes, and flushing of skin than those who did not apply products. A postal survey of licenced pet applicators and applicators working in veterinary surgeries in New Jersey found that 36% of respondents had experienced at least one of the 17 symptoms associated with insecticide application.³⁷ Only 27% of the sample participated in this survey, which may mean that these findings overestimate the proportion of applicators who develop symptoms. Both these surveys used self report of symptoms and did not measure acute or chronic exposures objectively.

Evidence for carcinogenicity at exposure levels similar to veterinarians

There is considerable interest in the possible carcinogenic effects of pesticides. Part of the difficulty of studying the effects of pesticides is that there are many different groups including insecticides, herbicides, and fungicides. Each group includes many different chemicals, each of which may have a different structure, a different mechanism of action, and different carcinogenicity. Although there are many studies which examine herbicides and their contaminants, for which the links with cancer are perhaps strongest, the interest for veterinarians is rather with organophosphate insecticides and carbamates, both of which are used on animals to control parasites.

Use of insecticides for flea and tick control in domestic pets is one method of exposure for veterinarians. Domestic use of insecticides has been investigated as a risk factor for childhood brain cancer in two case-control studies. Risk

was reported to be increased with use of pesticides on pets when the child was also exposed to pets³⁸ and with use of flea or tick products antenatally.³⁹ The possibility of recall bias in these retrospective studies must be considered to be quite high.

Use of flea and tick dips was found to be a risk factor for bladder cancer in dogs, especially overweight females⁴⁰ but the relevance of this to human carcinogenesis is unknown.

Although farmers have been found to have increased risks of lymphohaematopoietic cancers in meta-analyses and reviews,⁴¹⁻⁴² many of these studies considered farmers as one group. For pesticides, the most relevant comparison group for veterinarians is insecticide use in livestock farming and here I will review only studies which examined this particular exposure.

Three case-control studies of non-Hodgkin's lymphoma in rural regions of the United States found no significant increases for any insecticides used on livestock.⁴³⁻⁴⁵ Only one of the studies⁴³ found an increase in risk with use of organophosphates, which was small but significant. Three United States case-control studies were pooled to examine the risk of non-Hodgkin's lymphoma with use of lindane (an organochlorine used in dog shampoos and livestock sprays)⁴⁶ This study found a slight significant increase in risk of non-Hodgkin's lymphoma with ever use of lindane, which was mostly confined to those who used lindane >20 years previously. Self reports of the use of insecticide in farmers are considered to be reasonably accurate because they purchase and use the products themselves. Studies at the ecological level, which used county figures for use of insecticides as the exposure variable, have sometimes⁴⁷⁻⁴⁸ but not always⁴⁹ found increased rates of leukaemia and multiple myeloma.

INFECTIOUS AGENTS

Exposure levels

It has long been known that veterinarians are at increased risk of infections transmitted from animals to humans (zoonoses). The published serological surveys of veterinarians are summarised in table 1. Most of these studies have examined the classic zoonotic diseases such as brucellosis, Q fever, and toxoplasmosis. These diseases have not been associated with cancer;

however, the discrepancies between prevalences in veterinarians and the general population show that veterinarians are at high risk of zoonoses. It follows then that if certain zoonoses were associated with cancer, veterinarians would be one of the groups at high risk of cancer.

One survey of veterinarians for a known animal carcinogenic virus was conducted in 1973.⁵⁰ Six hundred and twenty six veterinarians had blood taken for testing for antibodies to feline leukaemia virus (FeLV) Only one veterinarian showed a definite positive result which suggests that human transmission of this virus is rare. However, it is possible that the techniques used at that time for testing for the presence of infection were not sensitive enough.⁵¹

Evidence for carcinogenicity at exposure levels similar to those of veterinarians

There are several well described viruses which cause cancer in various animals including bovine papilloma virus and FeLV.⁵² There are also several viruses known to cause cancer in humans including herpes papilloma virus which causes cervical cancer and Epstein-Barr virus which causes Burkitt's lymphoma and nasopharyngeal cancer.⁵² Also, it is known that some viruses, including cowpox, foot and mouth disease, and a range of arboviruses, are able to pass from animals to humans.

These facts have resulted in some speculation about the possibility that carcinogenic viruses in animals could be transmitted to humans where they could cause cancer.⁴¹⁻⁴²⁻⁵¹ Speculation has concentrated on lymphohaematopoietic cancers as there is already evidence that some of these types of tumours can be caused by viruses.

One line of investigation is to find whether the risks of lymphohaematopoietic cancer are higher in occupations in which there is contact with animals or animal products. Several cohort studies of butchers and meatcutters have, on the whole, shown no increase in lymphohaematopoietic cancers compared with national rates or with non-meatworkers in the same union⁵³⁻⁵⁵ although a subanalysis of poultry workers in one of these cohorts had an RR of 2.9 (95% CI 1.0 to 81)⁵⁶ The SMR for these poultry workers was not increased. A nested case-control study in the same cohort was

Table 1 Serological surveys of zoonoses in veterinarians

Organism	First author, year ^{ref}	Vets (n)	Positive prevalence (%)	Criterion for positive	Notes
Bartonella	Noah, 1997 ⁹⁵	198	8.1	>1/64	2% Prevalence in US blood donors
Brucella	Nowotny, 1997 ⁹⁶	137	0	?	
	Robinson, 1976 ⁹⁷	86	91 (3)	any (1/160)	
Coxiella	Schnurrenberger, 1964 ⁹⁸	844	6.3	1/20	17.4% Prevalence among general practitioners
	Morse, 1955 ⁹⁹	65	38 (1.5)	any (1/160)	
	Thibon, 1996 ¹⁰⁰	12	67 (3)	1/16 (1/320)	Healthy controls <5%
	Htwe, 1993 ¹⁰¹	275	23	1/16	Healthy controls <2%
	Marrie, 1985 ¹⁰²	65	17-49 (3)	1/8 (1/256)	
Leptospira	Schnurrenberger, 1964 ⁹⁸	844	7.6	1/4	20.7% Prevalence among large animal practitioners
	Nowotny, 1997 ⁹⁶	137	2.9	?	
	Schnurrenberger, 1978 ¹⁰³	381	2	1/100	
	Robinson, 1976 ⁹⁷	86	1	1/400	
	Schnurrenberger, 1964 ⁹⁸	844	0.8	1/16	
Toxoplasma	Morse, 1955 ⁹⁹	104	10	1/10	
	Nowotny, 1997 ⁹⁶	137	54.7	?	10.9% Prevalence among pregnant Norwegian women
	Robinson, 1976 ⁹⁷	86	3.4	1/512	

limited by small numbers and found non-significant increases in risks for subjects who worked with raw meat or killed animals.⁵⁷ In case-control studies, meat processors have been found to have significantly increased risks of Hodgkin's disease⁵⁸ and non-Hodgkin's lymphoma⁵⁹ in some but not all studies.⁴⁴ In two North American registry based studies, the occupation of meat cutting was not associated with increased risk of leukaemia.^{60 61} All of these studies were limited either by few cases or poor exposure classification.

Lung cancer in meat workers has also been examined with some cohort studies suggesting that pork butchers and packers have increased risks.^{54 55 62} In a case-control study nested in one of these cohorts it was found that ever working in the meat industry was associated with a 3.6-fold increase in risk of lung cancer (95% CI 0.7 to 17.9) after adjusting for age, sex, race, and smoking.⁶³ The risk was higher in those who had worked in the industry >10 years before diagnosis.

As discussed previously, the occupation of farming has also been associated with increased risks of lymphohaematopoietic cancers in some but not all studies. For zoonoses there are several studies that have attempted to examine livestock farmers for risk of lymphohaematopoietic cancers (table 2). The results from these studies are not entirely consistent although there is a suggestion that leukaemia may be associated with poultry and cattle farming. Livestock farmers may also have exposure to other possible carcinogens including different types of pesticides (as already discussed) and diesel exhaust.

Another line of approach is to determine whether cancer risk is increased by living in close contact with animals. The risk of lung cancer associated with keeping birds has been extensively investigated⁶⁴⁻⁶⁸ but there does not seem to be evidence for a link.⁶⁹

Feline leukaemia virus (FeLV) is a virus which, as its name suggests, causes leukaemia and lymphoma in cats. Simply living with a cat does not seem to increase the risk of leukaemia or lymphoma^{70 71} or lung cancer.⁶⁴ Also, there does not seem to be an increased risk of any type of cancer associated with living with a cat

known to have lymphoma.⁷² One early study suggested that exposure to sick cats might be associated with adult leukaemia but the type of sickness was not defined.⁷³

Similarly, bovine leukaemia virus causes leukaemia in cattle, but antibodies to it have not been detected in humans in close contact with infected cattle.⁷⁴ Some ecological studies suggest higher rates of leukaemia in areas with many cattle, or where outbreaks of bovine leukaemia virus had been reported but this has not been confirmed in case-control studies.^{75 76}

These studies of the risks of exposure to zoonoses are marred by poor exposure assessment. Not all those who live in a household with pets will be exposed to zoonoses, and neither is having no animals in the house a guarantee of non-exposure.⁷⁷ Also, the answers to questions about exposure to sick animals are prone to recall bias and non-specificity of the sickness.⁷⁷

Another line of inquiry has tried to determine whether viruses known to be carcinogenic in animals are transmitted to humans. Avian leukosis and sarcoma viruses (ALSV), reticuloendotheliosis viruses (REV), and Marek's disease virus (MDV) are known to cause cancers of the lymphatic and haemopoietic system in chickens and turkeys. During the 1960s and 1970s there was considerable interest in determining whether antibodies to these three viruses could be detected in exposed subjects. Most of these studies were negative although there were technical difficulties with the measurement of antibodies at that time.⁷⁸ Since then, the availability of more sensitive tests for virus detection has resulted in further studies which have concluded that antibodies to all three viruses are more common among poultry workers than among non-exposed controls.⁷⁹⁻⁸¹ Studies have not been able to detect FeLV in human serum samples or in cells from human cancers.^{82 83}

Studies of cancer in veterinarians

A Medline search was made for published studies of cancer in veterinarians since 1966 with all variations on the keywords

Table 2 Summary of case-control studies examining livestock farming and lymphohaematopoietic cancers

First author, year ^{ref}	Population	Cancer	Exposure assessment	Exposure	OR (95% CI)
Milham, 1971 ¹⁰⁴	Deaths in two US states	Leukaemia	Occupation on death certificate	Poultry farmer Dairy farmer Cattle farmer	p<0.05 p>0.05 p>0.05
Blair, 1979 ⁴⁷	Deaths in one US state, farmers only (year of birth 1901-43)	Leukaemia	Per capita agricultural characteristics	Poultry Cattle Pigs	1.6 (1.0 to 2.6) 1.7 (1.1 to 2.7) 2.0 (1.3 to 3.3)
Cantor, 1984 ⁴⁸	Deaths in one US state (excluding deaths in capital city) all farmers only	Multiple myeloma	Per capita agricultural characteristics	Poultry Cattle Pigs Dairy	1.6 (1.0 to 2.7) 1.2 (0.8 to 2.0) 1.3 (0.8 to 2.0) 1.3 (0.8 to 2.1)
Pearce, 1986 ¹⁰⁵	Incident registered cancers in New Zealand, cancer controls	Leukaemia	Occupation on cancer registration	Livestock farm Dairy farm Poultry farm 0 Cases	3.0 (1.2 to 7.3) 1.2 (0.4 to 3.7) 1.9 (1.0 to 3.6) 1.4 (0.8 to 2.5)
Pearce, 1986 ¹⁰⁶	Incident registered cancers in New Zealand, cancer controls	Multiple myeloma	Telephone interview, self reported occupation	Sheep farm Dairy farm Mixed farm Poultry farm	1.4 (0.8 to 2.5) 1.3 (0.6 to 2.6) 0.9 (0.1 to 8.4)
Clavel, 1995 ¹⁰⁷	Incident cancers in nine French hospitals	Hairy cell leukaemia	Self reported occupation	Cattle breeding Sheep breeding Pig breeding	1.9 (1.1 to 3.1) 1.8 (0.9 to 3.6) 1.4 (0.6 to 2.8)

veterinarians and cancer. Relevant articles cited in the retrieved articles were also obtained. One case-control study and six cohort studies were found which gave rates or risks of cancer specifically for veterinarians.

CASE-CONTROL STUDIES

It is rare for community based studies of cancer to report the risk for veterinarians separately as, in western countries, veterinarians account for only about 0.03% of the working population. As a result, most case-control studies combine the occupation of veterinarian with other professions or other health workers making it impossible to assess the risk of cancer specific to veterinarians. However, one case-control study of multiple myeloma based on occupation as recorded on death certificates did report the risk for veterinarians separately.⁸⁴ The investigators found a risk of multiple myeloma in veterinarians compared with all other occupations of 3.2 (95% CI 1.1 to 9.0) This was based on six cases of multiple myeloma in veterinarians out of nearly 12 000 cases.

COHORT STUDIES

Description of studies

All published cohort studies of cancer in veterinarians have been mortality studies (table 3). Mortality is a reasonable measure of risk for those cancers with a high case fatality rate such as lung cancer. However, incidence is a better measure of risk for most cancers.

There have been two published studies which calculated proportional mortality ratios (PMRs) from deaths in registered veterinarians, both performed in the United States.⁸⁵⁻⁸⁶ One obtained the list of deceased veterinarians from all obituaries in a veterinary journal between the years 1947 and 1977.⁸⁶ The other used deaths notified to veterinary registration boards between the years 1960 and 1992.⁸⁵ There have been four published cohort studies which presented standardised mortality ratios (SMRs) in registered veterinarians.⁸⁷⁻⁹⁰ All four cohort studies were performed during the

1950s and 1960s, one in Britain⁸⁹ and the other three in the United States. The cohorts were formed from lists of registered veterinarians and were followed up to ascertain deaths. Both PMRs and SMRs have well known potential problems as measures of effect.

Results from cohort studies

Veterinarians do not seem to differ greatly from the general population for deaths from all cancers combined (table 3) The only significant finding was a PMR of 118 in one of the mortality studies.⁸⁵ It would seem worth noting that veterinarians are usually considered to be a high socioeconomic group, and as such, may be expected to have a lower cancer mortality than the general population.

Veterinarians had about 30% lower risk of lung cancer in all four studies which reported that risk.⁸⁵⁻⁸⁶⁻⁸⁸⁻⁸⁹ This is consistent with veterinarians' higher socioeconomic status and increased health knowledge, both of which would be associated with lower rates of smoking.

Both studies that reported PMRs noted significantly increased PMRs for colon cancer.⁸⁵⁻⁸⁶ However, the one SMR study which presented results for colon cancer found the SMR to be only 103.⁸⁹ It may be that the PMR for colon cancer is affected by the few deaths from lung cancer.

The larger PMR study found significantly increased PMRs for brain tumours based on 28 cases.⁸⁶ Significantly increased risks of brain tumours were not reported in any other study.

Although increased death rates from melanoma were reported, these were based on few cases. An SMR of 727⁸⁸ was based on three deaths and PMRs of 325⁸⁵ and 161⁸⁶ were based on seven and 24 deaths respectively. One of the risk factors for melanoma is exposure to sun, and it might be argued that veterinarians who have large animal practices spend considerable time outdoors. The SMR study found that two of the three veterinarians with melanoma were general practitioners, and the

Table 3 Cohort studies of cancer in veterinarians

Cancer (ICD-9 code)	First author, year ^{ef}	Cases (n)	Finding
All cancers combined	Botts, 1966 ⁸⁷	21	SMR = 94
	Schnurrenberger, 1977 ⁹⁰	79	SMR = 112
	Fasal, 1966 ⁸⁸	29	SMR = 94
	Kinlen, 1983 ⁸⁹	228	SMR = 84
	Blair, 1982 ⁸⁶	832	PMR = 101
Stomach (151)	Miller, 1995 ⁸⁵	116	PMR = 118 (95% CI 101 to 138)
	Kinlen, 1983 ⁸⁹	26	SMR = 69
	Blair, 1982 ⁸⁶	47	PMR = 65 (p<0.005)
Colon (153)	Miller, 1995 ⁸⁵	5	PMR = 119 (95% CI 50 to 283)
	Kinlen, 1983 ⁸⁹	21	SMR = 103
	Blair, 1982 ⁸⁶	111	PMR = 134 (p<0.005)
Lung (162,163)	Miller, 1995 ⁸⁵	14	PMR = 169 (95% CI 101 to 282)
	Fasal, 1966 ⁸⁸	5	SMR = 68
	Kinlen, 1983 ⁸⁹	61	SMR = 65
	Blair, 1982 ⁸⁶	115	PMR = 62 (p<0.005)
	Miller, 1995 ⁸⁵	22	PMR = 69 (95% CI 47 to 103)
Melanoma (190)	Fasal, 1966 ⁸⁸	3	SMR = 727
	Miller, 1995 ⁸⁵	7	PMR = 325 (95% CI 162 to 652)
Skin cancer (190-191)	Kinlen, 1983 ⁸⁹	2	SMR = 81
	Blair, 1982 ⁸⁶	24	PMR = 161 (p<0.025)
Central nervous system (193)	Blair, 1982 ⁸⁶	28	PMR = 163 (p<0.01)
	Miller, 1995 ⁸⁵	3	PMR = 95 (95% CI 31 to 294)
All lymphoheamatopoietic (200-205)	Blair, 1982 ⁸⁶	112	PMR = 149 (p<0.005)
	Miller, 1995 ⁸⁵	12	PMR = 119 (95% CI 68 to 208)
Lymphoma (200-202)	Fasal, 1966 ⁸⁸	2	SMR = 103
	Kinlen, 1983 ⁸⁹	11	SMR = 83

third was a large animal practitioner.⁸⁸ Miller and Beaumont found that self employed and employee veterinarians had significantly increased PMRs from melanoma whereas government and educator veterinarians did not.⁸⁵ Blair and Hayes found the risk to be higher in non-small animal veterinarians.⁸⁶ Melanoma is also known to be more common in higher socioeconomic groups, which may be an alternative explanation of the findings, although it would not explain the higher rates in large animal veterinarians compared with small animal veterinarians.

Lymphohaematopoietic cancers are of interest in this group because of the finding that agricultural workers in general have increased risks of lymphohaematopoietic cancers. The largest study of veterinarians found a significantly increased PMR of 149 for all lymphohaematopoietic cancers combined.⁸⁶ Of the lymphohaematopoietic cancer types in this study, there were significantly increased PMRs for Hodgkin's disease (PMR=187, n=18) and "other lymphatic tissue" (ICD-7 202, 203, 205, PMR = 192, n=26). Smaller studies have tended not to find a significantly increased risk.

The increases in both melanoma and lymphohaematopoietic cancers are interesting in the light of recent discussion of a possible link between sun exposure, skin cancer, and non-Hodgkin's lymphoma. This theory is based on findings that skin cancer and non-Hodgkin's lymphoma are found in association more often than expected⁹¹⁻⁹² and some studies show that sun exposure and non-Hodgkin's lymphoma are related.⁹³⁻⁹⁴ This theory is still speculative but, if more evidence accumulates in its favour, it would make it less likely that the possible increases in risk of non-Hodgkin's lymphoma in veterinarians are associated with pesticides or zoonoses.

Conclusions

The few studies available which have considered the issue of cancer in veterinarians report a mortality from all cancers about the same as in the general population. The mortalities from lung cancer are significantly decreased, whereas there is some suggestion of increased mortality from lymphohaematopoietic cancers, melanoma, and possibly colon cancer. None of these studies have been able to assess the role of specific exposures in cancer risk, and all have used mortality rather than incidence.

Veterinarians have significant exposure to several known and potential carcinogens, particularly radiation, anaesthetics, insecticides, and animal viruses.

There are known risks of skin cancer, thyroid cancer, and leukaemia with exposure to x rays, but the doses received in veterinary practice are probably insufficient to cause major increases in risk, unless there are problems with the equipment or with radiology procedures. The carcinogenic risk from anaesthetics is probably negligible in this occupation. Insecticides for parasite control in large and small animal practices are potentially associated with lymphohaematopoietic cancers. The evidence for car-

cinogenic zoonotic organisms causing cancer in humans, although intriguing, is still speculative.

Studies of veterinarians that use better exposure assessment and examine incidence rather than mortality from cancer may shed light on risks not only for veterinarians but for a range of other occupations related to medicine and animals—such as animal handlers, veterinary nurses, dentists, radiographers, anaesthetists, and some farmers.

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