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Mortality in over 350,000 Insured Swedish dogs from 1995-2000: I. Breed-, Gender-, Age- and Cause-specific Rates

By *B. N. Bonnett*[1], *A. Egenvall*[2], *Å. Hedhammar*[3] and *P. Olson*[4]

[1]Department of Population Medicine, Ontario Veterinary College, University of Guelph, Guelph, Ontario, Canada N1G 2W1, [2]Department of Clinical Sciences, Faculty of Veterinary Medicine and Animal Science, Swedish University of Agricultural Sciences, SE-750 07 Uppsala, Sweden, [3]Department of Small Animal Clinical Sciences, Faculty of Veterinary Medicine and Animal Science, Swedish University of Agricultural Sciences, SE-750 07 Uppsala, Sweden, [4]Agria Insurance, PO 70306, SE-107 23 Stockholm, Sweden.

Bonnett BN, Egenvall A, Hedhammar Å, Olson P: Mortality in over 350,000 Insured Swedish dogs from 1995-2000: I. Breed-, gender-, age- and cause-specific rates. Acta vet. scand. 2005, 46, 105-120. – This study presents data on over 350,000 insured Swedish dogs up to 10 years of age contributing to over one million dog-years at risk (DYAR) during 1995-2000. A total of 43,172 dogs died or were euthanised and of these 72% had a claim with a diagnosis for the cause of death. The overall total mortality was 393 deaths per 10,000 DYAR. Mortality rates are calculated for the 10 most common breeds, 10 breeds with high mortality and a group including all other breeds, crudely and for general causes of death. Proportional mortality is presented for several classifications. Five general causes accounted for 62% of the deaths with a diagnosis (i.e. tumour (18%), trauma (17%), locomotor (13%), heart (8%) and neurological (6%)). Mortality rates for the five most common diagnoses within the general causes of death are presented. These detailed statistics on mortality can be used in breed-specific strategies as well as for general health promotion programs. Further details on survival and relative risk by breed and age are presented in the companion paper (*Egenvall et al.* 2005).

database; incidence.

Introduction

Population data on the rates and causes of death in dogs provide useful information on several levels. Breed-specific rates and estimates of the proportion of deaths in a breed due to certain causes can describe the current or ongoing health problems in that breed. These may inform health promotion strategies and their monitoring. The age pattern of death, especially estimates of survival to certain ages, is informative for current and prospective owners of a breed and for veterinarians and researchers. Comparing similarities and differences in patterns of mortality across breeds or genders may suggest theories about disease causation and direct research as to whether a certain cause of death may be a function of, for example, genotype or phenotype, conformation, physiology, temperament or usage. Undoubtedly dog-breeding practices have had an impact on the general health of the canine population as well as on the occurrence of inherited diseases (*Ott* 1996). Quantifying the disease burden in a population, either within or across breeds, is necessary to monitor changes in disease and death rates over time that may relate to natural causes, environmental changes or human interventions.

Monitoring disease in animal populations may also inform efforts to identify, for example, environmental causes of deaths in humans.

In several studies tumours have been indicated as the most common cause of death in dogs, followed by various other diseases (*Bronzon* 1982, *Bernardi* 1988, *Bredal et al.* 1994, *Bonnett et al.* 1997). A recent study on a British insurance database indicated that tumours are a frequent cause of claims (*Dobson et al.* 2002). In some studies it has been shown that different causes of death are related to the age of the dog (*Anderson & Rosenblatt* 1965, *Bronzon* 1982, *Bernardi* 1988, *Bredal et al.* 1994, *Deeb & Wolf* 1994, *Eichelberg & Seine* 1996). For example, *Bredal et al.* (1994) showed that the mean age at death of Bernese mountain dogs that died from trauma was almost four years. In the same study, the mean age at death of those Bernese mountain dogs that had died of cancer was almost seven years. In earlier work by these authors trauma (especially road traffic accidents) was a common cause of death in Swedish dogs (*Bonnett et al.* 1997). The underlying risk factors and causes, and therefore prevention strategies, for tumours and trauma are quite different.

The Agria (Agria Animal Insurance, PO 70306, SE-107 23 Stockholm, Sweden) insurance database has previously been used to study morbidity and mortality in Swedish dogs (*Bonnett et al.* 1997, *Egenvall et al.* 2000a-c). The age pattern, irrespective of cause of death, based on death before 10 years of age, has also been presented for a few selected breeds (*Egenvall et al.* 2000c). It has been shown that the demographic validity (breed, age, gender) of the database is excellent, while the diagnostic validity is adequate (*Egenvall et al.* 1998). As there are now six years of data available for analysis, the database provides further opportunities to study causes of death in relation to breed, gender and age for various diagnostic categories of death.

The objective of this study is to describe the occurrence of general causes of death in Swedish dogs insured during 1995 to 2000 by presenting overall and cause-specific mortality rates and proportional mortality by breed. The age pattern of general causes of death within several breeds/groups and the effect of gender will be examined. Further details on individual breeds, including survival analysis and relative risk will be presented in the companion paper (*Egenvall et al.* 2005).

Materials and methods

Insurance data

Dogs covered by life insurance from 1995 to 2000 in a Swedish insurance company (Agria) were included in this study. Most dogs had been enrolled in insurance as puppies, but dogs could have entered the insurance program until they were six years of age until year 1996 and after that at any age. Eight percent of the dogs in the database entered after three years of age. The insurance process has previously been described in detail (*Bonnett et al.* 1997, *Egenvall et al.* 2000a). Dogs in this analysis were only covered for life until 10 years of age.

Deaths of life-insured dogs could be registered in several ways. Most often, the company received a signed claim form from the attending veterinarian when the dog died or was euthanised. In other situations, when an animal died and a veterinarian was not involved, for example some traumatic deaths, the claim form was filled out and signed by the owner and two independent persons who certified their knowledge of the cause of death or loss of the animal. Both natural deaths and deaths from euthanasia were included (not differentiated in the database). Dogs that died but for which no claim was submitted were generally recorded as 'dead – not claimed'. As owners terminate their policies upon a dog's death, most or all of these deaths are captured in the database, however there is no recorded diagnosis for the cause of death.

Data from 1995 to 2000 on all dogs covered for life insurance at Agria were downloaded to a personal computer. Variables used were breed, date of birth, date of death, gender (male /female, not neuter status), diagnostic code for death, date when the dog entered or left the insurance program and information on the type of insurance for which the dog was enrolled.

Many dogs originally insured before 1993 had the year of birth accurately recorded (*Egenvall et al.* 1998), but not the date and month. However, most of the dogs have had their date and month of birth updated since then. The dogs with unknown date of birth were said to have been born the 2nd of July (the middle of the year).

Breeds were based on classification codes from the Swedish Kennel Club. Non-purebred dogs were classified as mongrels. Some breeds were combined as they were considered to share a common gene pool. Specifically, dachshund included all normal-sized dachshunds, except for the longhaired, miniature dachshund consisted of all miniature variants and St Bernard included both long-haired and smooth-haired dogs of that breed. Poodle included both toys and miniatures.

Diagnoses

Since the first of January 1995 a hierarchical registry (*Swedish Animal Hospital Association* 1993) has been used at the insurance company to assign diagnostic codes to each claim. This registry contains more than 8,000 alpha-numerical codes. The registry is based on the 14 following different major organ systems: integumentary, digestive, genital, respiratory, skeletal, auditory, joints, ocular, urinary, cardiovascular, endocrine, nervous, muscular and unspecified. System 'unspecified' contains signs of disease that cannot be attributed to a specific system as well as diseases that are considered to involve the whole animal, such as infectious diseases and all parasitic conditions. Ten major process groups can be assigned within each system: symptomatic, developmental, degenerative, circulatory, inflammatory, immunologic, neoplastic, traumatic, toxic and idiopathic (details, see *Egenvall et al.* 2000b). Within all systems except endocrine, sub-divisions of the organ system can be included. In the absence of a specific diagnosis, a veterinarian can assign "dead- no diagnosis" within system unspecified. In the database each claim can only have one diagnostic code associated with it and that is based on the diagnosis provided by the attending veterinarian.

For this study, the registered causes of death were partitioned into six general categories – tumours, trauma, locomotor disorders, heart, neurological and other problems. Tumours were those diagnoses listed under process neoplastic. The diagnostic category trauma included all diagnoses that were listed as traumatic processes; locomotor disorders were all those in systems skeletal, muscles and joints, except for the traumatic or neoplastic processes. Similarly, the diagnostic category heart consisted of all heart diagnoses, and neurological disorders included all diagnoses said to emanate from the nervous system, except for those said to be neoplastic or traumatic in origin. Cases with the diagnosis epileptiforme seizures were included under the diagnostic category neurological (from system unspecified). The specific diagnosis cruciate rupture was included under the diagnostic category locomotor and gastric dilatation/volvulus was included under the diagnostic category other (both from the traumatic process). All diagnoses that did not belong in any of the preceding categories were assigned to 'other'.

Analyses

The overall and breed-specific total mortality were calculated as mortality rates (MR) with exact denominators (the sum of each animal's total time of observation) and all deaths in the numerator. If a dog left the insurance during a year for reasons other than death, it was regarded as censored as of that date (leaving the database during the study period). The diagnostic MR numerator included only dogs with a settled claim that included a diagnostic code (although this could be 'no diagnosis' as specified by the veterinarian). The time at risk was either from the 1st of January 1995 or the date of enrolment for dogs enrolled after that date until the dog died or became censored (not later than 31st of December year 2000). Mortality rates were also calculated by diagnostic category within breed and for the five most frequent specific diagnoses within each diagnostic category. Mortality rates were multiplied by 10,000 to be interpreted as the number of deaths per 10,000 dog-years at risk (DYAR). Standard errors (SEs) for MRs have been constructed taking the root of the number of cases and dividing by the DYAR (*Breslow and Day* 1987), then multiplying by 10,000 (rates are presented as per 10,000 DYAR). Confidence intervals (95% CIs) have been constructed around the rates; rate ± 1.96*SE.

Data have been presented for the 10 most common breeds as well as for the 10 breeds with the highest diagnostic mortality. For a breed to be included in the high risk group there had to be at least 1,800 DYAR in the breed-specific denominator. Data for all remaining breeds were combined in one category (other breeds).

Total proportional mortality by breed was calculated (number of deaths in a breed or breed group / total deaths). Proportional mortality was calculated by diagnostic categories for all dogs and within breed (e.g. number of deaths in a breed due to the diagnostic category / total deaths for that breed). The proportional mortality within diagnostic category (the number of deaths from that cause in a certain breed / total deaths due to that cause) was presented for certain breeds and causes. For specific diagnoses the proportional mortality was calculated (the number of deaths due to a specific diagnosis within a diagnostic category / total dead within that diagnostic category). Most proportional mortalities are rounded to the nearest whole percent.

The age-specific and age- and diagnostic category-specific MRs for total and diagnostic mortality for the common, high risk and other breed groups were constructed using the SMOOTH macro (*Allison* 1995), which computes age-specific hazards from the baseline survival function computed by the SAS (SAS Institute Inc., Cary, NC, 27513, USA) procedure PHREG (Cox regression). The macro provides a smoothed estimate of the hazard curve using a kernel smoothing method. This involves arbitrarily setting the WIDTH parameter, which influences the degree of smoothing, to achieve a reasonable curve; in this case one-tenth of the range of event times was chosen. The rates were plotted against age, and the graphs are presented using different scales to adjust for marked differences in disease rates across breed groups.

Cox regression was also used to analyse whether the gender effect (male as baseline) was significant with respect to total or diagnostic mortality as well as for diagnostic categories within breeds. The direction and magnitude of the associations are presented using MR ratios (MRR, equivalent to hazard ratios) from regressions run separately on each breed with gender as the only covariate. The proportional hazards assumption was investigated by plotting the natural logarithm of the cumulative hazard, from Cox regression without covariates as described above, against the log of DYAR. This was done for total and diagnostic mortality, as well as the diagnostic categories by the "common/high-risk/other" groups. A value of P≤0.05 was considered significant. Confidence intervals (95%) are included for total and diagnostic mortalities.

Results

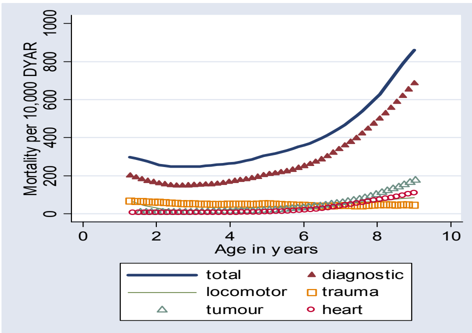
Altogether 353,125 dogs contributed to 1,098,358 DYAR. The dogs were from 332 breed designations. A total of 43,172 dogs died or were euthanised, and of these 31,057 (72%) had a claim with a diagnosis for the cause of death. The overall total mortality was 393 deaths per 10,000 DYAR for life-insured dogs up to 10 years of age and the diagnostic mortality was 283 deaths per 10,000 DYAR. The 10 most common and the 10 highest risk breeds are listed in Table 1 that also shows the diagnostic and total MRs (all deaths), the actual

Table 1. The dog-years at risk (DYAR), the total proportional mortality, the diagnostic (deaths with a diagnosis) and total mortality rate (all deaths) with 95% confidence intervals (95% CI's) within breed for dogs life-insured at Agria[1] from 1995-2000 by breed and breed group, as well as the percentage of total deaths with a registered diagnosis. The breeds are ranked by diagnostic mortality within breed group.

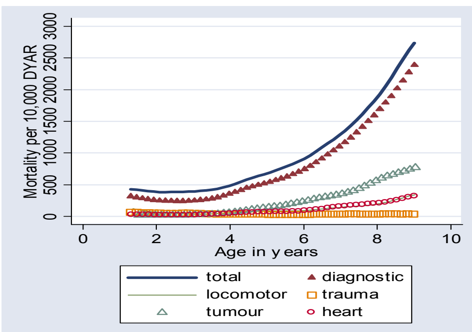
Group Breed	DYAR	Tot. prop. Mort. %[2]	Diagnostic mortality	Total mortality	Of total deaths with a diagn. %
			per 10,000 DYAR (95% CI)		
CKC spaniel[3a]	26,732	3.4	469 (443-495)	541 (513-569)	87
German shepherd	80,049	11.7	450 (435-465)	634 (616-651)	71
Drever	29,337	3.8	411 (388-434)	552 (525-579)	74
Dachshund	47,248	3.8	268 (253-283)	346 (329-363)	77
Labrador retriever	56,367	3.4	212 (200-224)	263 (249-276)	81
Springer spaniel[3b]	26,679	1.9	211 (193-228)	302 (281-323)	70
Mongrel	41,323	4.0	185 (172-195)	413 (393-432)	45
Golden retriever	68,643	3.9	184 (174-194)	243 (232-255)	76
Poodle (min/toy)	23,395	1.4	173 (156-190)	252 (232-273)	69
Min dachshund[3c]	30,876	1.6	168 (154-183)	230 (213-247)	73
Total COMMON[4]	430,649	38.8	279 (274-284)	389 (383-394)	72
Irish wolfhound	1,957	0.7	1,319 (1,158-1,480)	1,574 (1,398-1,750)	84
St Bernard	2,152	0.6	902 (775-1,028)	1,222 (1,074-1,370)	74
Great dane	3,195	0.8	892 (789-996)	1,114 (999-1,230)	80
Bernese mtn dog [3d]	10,534	2.1	753 (700-805)	854 (799-910)	88
Newfoundland	6,828	1.5	728 (664-792)	917 (845-989)	79
Dobermann	6,237	1.3	723 (656-790)	932 (856-1,007)	78
Leonberger	5,823	1.2	708 (639-776)	860 (785-936)	82
Boxer	11,078	1.6	554 (510-598)	629 (582-676)	88
Greyhound	3,772	0.6	541 (147-615)	740 (653-826)	73
Pyrenees	2,038	0.4	530 (430-630)	761 (641-880)	70
Total HIGH-RISK[5]	53,614	10.8	712 (689-734)	870 (845-895)	82
OTHER[6]	614,095	50.4	248 (244-252)	355 (350-359)	70
TOTAL all breeds	1,098,358	100	283 (280-286)	393 (389-397)	72

[1] - Agria Insurance, PO 70306, SE-107 23 Stockholm, Sweden
[2] - Number of deaths in breed or group / total number of deaths
[3] - Breed names: [3a] - Cavalier King Charles spaniel, [3b] - English springer spaniel, [3c] - miniature dachshund,
[3d] - Bernese mountain dog
[4] - 10 most common breeds in the database
[5] - 10 breeds with highest diagnostic mortality, among breeds with at least 1,800 DYAR
[6] - All breeds not included in common or high risk

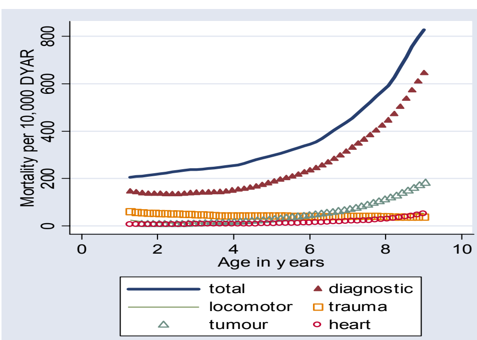
1a. Common breeds (note scale):



1b. High-risk breeds (note scale):



1c. Other breeds (note scale):



Figures 1a-c. The total mortality, the diagnostic mortality and the diagnostic category-specific mortalities by age for dogs in the 10 common breeds, 10 high-risk breeds and in other breeds.

DYAR and the proportion of all deaths by breed. Breeds are presented in order of decreasing diagnostic MR within the common and high-risk groups. For example, for German shepherd dogs the total mortality was 634 deaths per 10,000.

Within most breeds approximately 70% of dead dogs had a diagnosis registered. For Cavalier King Charles spaniels, Bernese mountain dogs and boxers 85% or more had a recorded cause of death. However, in mongrels only 45% had a registered diagnosis.

Figures 1a to 1c present the age pattern for total and diagnostic mortality rates for common, high-risk and other breeds respectively. The difference between total and diagnostic mortality is relatively constant across ages. Figures 1a to 1c also show the age pattern for the diagnostic category-specific MR. Details on the age pattern for causes of death in specific breeds and further analysis of relative risk across breeds is presented in the companion paper (*Egenvall et al.,* 2005).

Table 2 presents the overall diagnostic category-specific MR as well as the proportional mortality within breed for the common, high-risk and other breed groups, specific breeds and all dogs. As an example, in Cavalier King Charles spaniels there were 246 deaths per 10,000 DYAR in the diagnostic category heart that account for 52% of all deaths in that breed. In addition, heart deaths in the Cavalier King Charles spaniel represent 28% of all deaths due to a heart diagnosis in the insured population (data not shown). In all breeds, between 50 and 69% of the disease burden occurred under the five named diagnostic categories, the remainder under other causes of disease (table 2).

Table 3 presents the MRRs from the Cox regression for the effect of female compared to male for total, diagnostic and category-specific mortality. A MRR of <1 indicates that females are less likely to die of a given cause, and the in-

Table 2. The breed- and diagnostic category-specific mortality (MR) per 10,000 dog-years at risk (DYAR) with confidence intervals (95% CI) and the breed proportional mortality within diagnostic category (BP) for dogs life-insured at Agria[1] from 1995-2000.

GROUP Category Breed	MR (95% CI)[2] BP%[3]					
	Tumour	Trauma	Locomotor	Heart	Neuro	Other
CKC spaniel[4a]	24 (18-30) 5	22 (16-28) 5	16 (11-21) 3	246 (227-265) 52	15 (11-20) 3	145 (131-160) 31
German shepherd	71 (65-77) 16	33 (29-37) 7	122 (114-129) 27	12 (10-14) 3	19 (16-22) 4	193 (183-202) 43
Drever	29 (23-35) 7	201 (185-217) 49	20 (15-26) 5	10 (6-13) 2	15 (10-19) 4	136 (122-149) 33
Dachshund	21 (17-26) 8	100 (91-109) 37	44 (38-50) 16	26 (21-30) 10	6 (4-8) 2	71 (63-78) 26
Labrador retriever	45 (39-50) 21	21 (17-25) 10	61 (55-67) 29	7 (5-9) 3	11 (9-14) 5	67 (60-74) 32
Springer spaniel[4b]	44 (36-52) 21	22 (17-28) 11	12 (8-16) 6	10 (7-14) 5	19 (14-24) 9	103 (91-115) 49
Mongrel	34 (29-40) 19	46 (40-53) 25	12 (8-15) 6	6 (4-8) 3	14 (11-18) 8	73 (65-81) 39
Golden retriever	55 (50-61) 30	14 (11-16) 7	28 (24-32) 15	8 (6-10) 4	17 (14-20) 9	62 (57-68) 34
Poodle	18 (12-23) 10	38 (30-46) 22	12 (8-17) 7	6 (3-9) 3	13 (8-17) 7	86 (74-98) 50
Min dachshund[4c]	6 (3-9) 4	82 (72-92) 49	33 (27-39) 14	3 (1-5) 2	5 (2-7) 3	40 (33-47) 23
COMMON[5]	41 (39-43) 15	51(49-53) 18	47 (45-49) 17	25 (23-26) 9	14 (13-15) 5	102 (99-105) 36
Irish wolfhound	296 (220-373) 22	56 (23-89) 4	148 (94-202) 11	327 (247-407) 25	31 (6-55) 2	460 (365-555) 35
St Bernard	172 (117-227) 19	28 (6-50) 3	126 (78-173) 14	158 (105-211) 18	88 (49-128) 10	330 (253-407) 37
Great dane	119 (81-157) 13	56 (30-82) 6	119 (81-157) 13	178 (132-225) 20	53 (28-79) 6	366 (300-433) 41
Bernese mtn dog[4d]	306 (272-339) 41	41 (29-53) 5	154 (130-177) 20	15 (8-23) 2	22 (13-31) 3	215 (187-244) 29
Newfoundland	105 (81-130) 14	37 (22-51) 5	174 (143-206) 24	149 (120-178) 21	16 (7-26) 2	246 (209-283) 34
Dobermann	168 (136-201) 23	69 (48-90) 10	115 (89-142) 16	82 (59-104) 11	19 (8-30) 3	269 (229-310) 37
Leonberger	197 (161-234) 28	22 (10-34) 3	88 (64-112) 12	101 (75-127) 14	12 (3-21) 2	287 (243-330) 41
Boxer	203 (177-230) 37	18 (10-26) 3	55 (41-69) 10	41 (29-52) 7	63 (48-78) 11	174 (150-199) 31
Greyhound	58 (34-83) 11	135 (98-172) 25	101 (69-133) 19	34 (16-53) 6	21 (7-36) 4	191 (147-235) 35
Pyrenees	108 (63-153) 20	29 (6-53) 6	128 (79-177) 24	29 (6-53) 6	49 (19-79) 9	186 (127-246) 35
HIGH-RISK[6]	190 (178-201) 27	44 (38-50) 6	116 (107-125) 16	83 (76-91) 12	34 (29-39)5	245 (231-258) 34
OTHER[7]	44 (42-46) 18	46 (45-48)19	24 (23-25) 10	14 (13-15) 6	18 (17-19)7	102 (99-104) 41
Total all breeds	50 (49-51) 18	48 (47-49) 17	38 (37-39) 13	22 (21-22) 8	17 (16-18) 6	109 (107-110) 38

[1] - Agria Insurance, PO 70306, SE-107 23 Stockholm, Sweden
[2] - MR = number of deaths due to diagnostic category in a breed / DYAR for that breed
[3] - BP = number of deaths due to diagnostic category in a breed / total deaths in that breed
[4] - Breed names: 4a- Cavalier King Charles spaniel, [4b] - English springer spaniel, [4c] - Miniature dachshund, [4d] - Bernese mountain dog
[5] - 10 most common breeds
[6] - 10 breeds with highest diagnostic mortality, among breeds with at least 1,800 DYAR
[7] - All breeds not included in common or high risk

verse of the MRR represents the likelihood of a female not dying, compared to males or, alternatively, how much more likely males are to die compared to females. Ratios presented in brackets were not significant at $P<0.05$. Confidence intervals (95%) are presented for the total and diagnostic mortalities. The proportional hazards assumption was judged to be adequately satisfied in most plots.

Tables 4 lists, for each diagnostic category, the five most common specific diagnoses together with the diagnosis-specific MR for the whole population. The proportional mortality by specific diagnosis within category (proportion of all deaths in that diagnostic category that were due to the specific diagnosis) is presented overall for each specific diagnosis. 'Dead-no diagnosis' is the most common diagnosis in the category other with an incidence rate of 19 per 10,000 DYAR for all dogs combined. This re-

Table 3. Mortality rate ratios (MRR) for the effect of female compared to male gender, for the total mortality, diagnostic mortality, as well as the diagnostic category-specific survival derived from breed-specific Cox regressions. Estimated ratios are given in brackets when they were not significant ($p \geq 0.05$). The data are from dogs life-insured at Agria[1] between years 1995-2000. Confidence intervals (95% CIs) are included for the total and diagnostic mortality rates.

Group Breed	Total mortality	Diagnostic mortality	Tumour	Trauma	Locomotor disorders	Heart	Neurologic disorders	Other
CKC spaniel [2a]	0.8 (0.7-0.8)	0.8 (0.7-0.9)	(1.6)	(0.9)	(0.6)	0.6	(1.1)	1.4
German shepherd	0.8 (0.7-0.8)	0.8 (0.7-0.8)	1.2	(1.0)	0.7	(0.7)	(0.8)	0.6
Drever	0.8 (0.8-0.9)	(0.9) (0.8-1.0)	1.7	0.7	(1.1)	(0.8)	0.5	(1.1)
Dachshund	0.8 (0.7-0.9)	(0.9) (0.8-1.0)	1.8	(1.0)	0.6	0.5	(0.8)	(1.2)
Labrador retriever	0.8 (0.7-0.8)	0.8 (0.7-0.9)	(1.2)	0.6	0.7	(0.6)	(0.6)	(0.9)
Springer spaniel [2b]	0.7 (0.6-0.8)	0.8 (0.7-1.0)	1.6	(1.0)	(0.7)	0.4	0.5	0.7
Mongrel	0.7 (0.7-0.8)	(0.9) (0.8-1.1)	(1.3)	(0.8)	(0.7)	(0.8)	(0.6)	(1.0)
Golden retriever	0.9 (0.8-1.0)	(1.0) (0.9-1.1)	(1.1)	(0.8)	(0.9)	(0.9)	0.6	1.2
Poodle (min/ toy)	(0.9) (0.8-1.1)	(1.0) (0.8-1.2)	2.1	(0.7)	(0.6)	(0.4)	(0.9)	(1.2)
Min dachshund [2c]	0.7 (0.6-0.8)	(0.9) (0.7-1.0)	(1.9)	0.7	(0.8)	(1.1)	(1.4)	(1.1)
Total COMMON [3]	0.8 (0.8-0.8)	0.9 (0.8-0.9)	1.3	0.9	0.7	0.6	0.7	0.9
Irish wolfhound	(0.9) (0.7-1.1)	(0.8) (0.7-1.1)	(1.0)	(0.6)	(0.5)	(0.6)	(0.4)	(1.0)
St Bernard	0.8 (0.6-1.0)	(0.8) (0.6-1.1)	(1.2)	(1.8)	(1.5)	0.3	0.3	(1.0)
Great dane	0.6 (0.5-0.7)	0.7 (0.5-0.8)	(0.9)	(1.3)	(0.7)	0.2	(0.4)	(0.9)
Bernese mtn dog [2d]	0.8 (0.7-0.9)	0.8 (0.7-0.9)	0.7	0.4	(1.0)	(0.8)	0.4	(0.9)
Newfoundland	0.8 (0.7-1.0)	(0.9) (0.7-1.1)	(1.4)	(0.9)	0.5	0.4	(1.1)	0.8
Dobermann	0.7 (0.6-0.9)	0.8 (0.7-0.9)	(1.2)	(1.3)	(0.8)	0.5	(0.3)	(1.2)
Leonberger	0.8 (0.7-0.9)	(0.9) (0.7-1.1)	(1.0)	(1.6)	0.4	(0.7)	(2.3)	(1.0)
Boxer	(1.0) (0.8-1.1)	(1.0) (0.8-1.2)	(1.0)	(1.2)	(0.9)	(0.7)	(1.0)	(1.2)
Greyhound	0.6 (0.5-0.8)	0.5 (0.4-0.7)	(0.5)	(1.1)	0.4	0.3	(0.1)	0.5
Pyrenees	0.6 (0.4-0.8)	0.6 (0.4-0.8)	(0.9)	(0.5)	(0.6)	(0.1)	(0.5)	0.5
Total HIGH-RISK [4]	0.8 (0.7-0.8)	0.8 (0.8-0.9)	(0.9)	(0.9)	0.7	0.5	0.6	(1.0)
OTHER [5]	0.8 (0.8-0.8)	0.9 (0.9-0.9)	(1.1)	0.8	0.7	0.5	0.7	(1.0)
TOTAL all breeds	0.8 (0.8-0.8)	0.9 (0.9-0.9)	1.1	0.8	0.8	0.6	0.7	(1.0)

[1]Agria Insurance, PO 70306, SE-107 23 Stockholm, Sweden
[2] - Breed names: [2a] - Cavalier King Charles spaniel, [2b] - English springer spaniel, [2c] - miniature dachshund, [2d] - Bernese mountain dog
[3] - 10 most common breeds in the database
[4] - 10 breeds with highest diagnostic mortality, among breeds with at least 1,800 DYAR
[5] - All breeds not included in common or high risk

presents 6.8% of all deaths for which a cause was registered (data not shown). Note also that the second and third of the tumour diagnoses are "lymphosarcoma, blood and bloodproducing organs" and "lymphosarcoma, whole animal" (two diagnoses used interchangeably to a large degree in practice).

The percent of total mortality in each diagnostic category that is explained by the five diagnoses is also shown in Table 4. The five specific diagnoses represented between 33 and 82% of all deaths in each diagnostic category. Several of the coded diagnoses are, however, rather non-specific, e.g. heart problem.

Discussion

The insured population

The large database used in this study has several advantages, but of course extrapolation of the information must proceed with some cau-

Table 4. The overall mortality rate per 10,000 dog-years at risk (DYAR), the number dead and the specific diagnosis proportional mortality (SP) overall for the five most common specific diagnoses within diagnostic category for all dogs life-insured at Agria[1] between years 1995-2000.

Diagnostic category (SP:5)[2]	Specific diagnosis	Number of deaths	Mortality (per 10,000 DYAR)	SP[3]
Tumour (39%)	Mammary tumour	542	5 (5-5)	10
	Lymphosarcoma, blood and bloodproducing organs	501	5 (4-5)	9
	Lymphosarcoma, whole animal	393	4 (3-4)	7
	Liver tumour	385	4 (3-4)	7
	Tumour in lung	339	3 (3-3)	6
Trauma (73%)	Car accident	2342	21 (20-22)	44
	Lost	416	4 (3-4)	8
	Drowning	378	3 (3-4)	7
	Train accident	347	3 (3-3)	7
	Lost during hunting	344	3 (3-3)	7
Locomotor disorders (54%)	Hip dysplasia	844	8 (7-8)	20
	Disc herniation	622	6 (5-6)	15
	Lumbosacral instability	322	3 (2-3)	8
	Chronic deforming arthrosis, elbow joint	294	3 (2-3)	7
	Cruciate rupture	176	2 (1-2)	4
Heart (77%)	Signs of heart failure	723	7 (6-7)	31
	Signs of heart disease, no cause defined	354	3 (3-4)	15
	Cardiomyopathy	295	3 (2-3)	12
	Dilated cardiomyopathy	223	2 (2-2)	9
	Endocardiosis (myxomatous valvular disease)	218	2 (1-2)	9
Neurologic (82%)	Idiopathic epilepsy	968	9 (8-9)	52
	Epileptiforme seizures	350	3 (3-4)	19
	Signs of disease without defined cause, cerebrum	115	1 (1-1)	6
	Acute inflammatory conditions, meninges	57	0.5 (0.4-0.7)	3
	Progressive chronic degenerative radiculomyelopathy	49	0.4 (0.3-0.6)	3
Other (33%)	Dead- no diagnosis	2111	19 (18-20)	18
	Pyometra	544	5 (4-5)	5
	Signs of disease, no cause defined, kidney or/and ureters	497	5 (4-5)	4
	Diabetes mellitus	474	4 (4-5)	4
	Liver insufficiency	358	3 (3-4)	3

[1] - Agria Insurance, PO 70306, SE-107 23 Stockholm, Sweden
[2] - SP:5 = number dead within 5 specific diagnoses / number dead in this diagnostic category)*100
[3] - SP = specific diagnosis proportional mortality = number dead with the specific diagnosis / number dead in this diagnostic category)*100

tions. In previous studies, it has been shown that the accuracy of the demographic data in the insurance database was excellent (*Egenvall et al.* 1998) and that the population insured at Agria is quite similar to the general population of dogs in Sweden (*Egenvall et al.* 1999). The major differences between the insured population and the total Swedish population are that a lower proportion of mongrels are insured, and there are, of course, more older dogs in the general population.

Some of the earlier studies were on limited years of data, and the earliest one used only breed-level data (*Bonnett et al.* 1997, *Egenvall et al.* 2000a-c). In the present study six years of data have been included, dogs could be followed individually and it was possible to calculate the actual time of observation for each dog. This is a dynamic population (dogs may enter or leave the database) and therefore mortality is best expressed with MRs that express the occurrence of death based on the actual time at risk. Compared to most of the published studies on death in breeds of dogs, the database used in this study provides a large number of cases (for example deaths by breed or by diagnostic category) over several years, making the results less prone to random error. It is now possible to present the mortality with respect to the effect of for example age, breed and diagnosis simultaneously. Comparisons are facilitated across breeds as to the relative burden of disease. For example, golden retrievers are one of the most common breeds of dog in Sweden, with over 68,000 dog years at risk in this database (6% of the insured population, data not shown). Irish wolfhounds provide less than 2,000 DYAR. However, based on 10,000 DYAR there were over 1,500 deaths in the Irish wolfhound and only 243 in golden retrievers in insured dogs under 10 years of age. One might postulate differences due to size, i.e. a giant breed vs. a large one, however, breeds of a similar size to golden retrievers, e.g. Bernese mountain dogs, dobermanns and boxers also have a much higher mortality.

As space does not allow presentation of information on all breeds in the database, the decision was made to include the 10 most common breeds, a group of breeds with both high rates of death and a sufficient number of dogs to ensure good validity for calculated rates and then to group all other breeds in one group. The 20 specific breeds accounted for approximately 45% of the insured population and one-half of the deaths. The information provided on the group of all other breeds and for the whole population offers a useful comparison.

It is important to note that puppy mortality is not included in the present study and dogs are only included up to 10 years of age. However, if one considers that the first 10 years represents the major part of an expected lifespan for many breeds, and that it is preferable to target prevention strategies at diseases occurring relatively early in life, the information presented is highly relevant to veterinarians in clinical practice, researchers and for dog organisations, breeders and owners. Although the mortality due to most causes increased with age, the rate of tumour deaths started to rise earlier in the high-risk breeds. This may be related to a faster rate of aging, i.e. certain breeds may be biologically older at a given chronological age compared to other breeds (*Albert et al.* 1994, *Egenvall et al.* 2000c). On the other hand, the rate of trauma is relatively higher in younger ages in common and other breeds, perhaps related to behaviour.

It is important to take into account the age pattern of disease and possible differences in age distribution across groups when examining competing causes of death, as in this and the companion paper (*Egenvall et al.* 2005). In order to die of causes of death that are a result of aging (for example some cancers) one must survive to an increased age. This must also be considered when interpreting proportional estimates for mortality, especially from certain sources of data (e.g. *Craig* 2001). Cox regression, assuming proportional hazards over the analysed period, is used to analyse time to an event, in this case death, rather than simply proportions of a breed that have died.

One drawback with the insurance database is that neuter status is not included. Although, there may be an increasing trend for elective spaying and neutering recently in Sweden, data from 1998 suggest that only about seven per cent of Swedish bitches and less than four per cent of males (all ages) are neutered (*Egenvall et al.* 1999). This estimate includes dogs spayed both for medical conditions and non-medical reasons.

Diagnostic considerations

Because owners tend to terminate their policy when an animal has died, even if they have not submitted a claim, the total mortality rate presumably includes almost all deaths. Any unrecorded dead dogs would at least be censored (in the analysis) when their policy was terminated. Only those for whom a claim is processed, however, have a diagnosis entered for the cause of death (although this may include, dead-no diagnosis, if provided by a veterinarian). A diagnosis was specified for approximately 70% of all deaths. For some breeds over 85% of deaths had a recorded cause, however, for mongrels 45% had a diagnosis. The possible reasons that the death of a life-insured animal would not have a cause recorded include the following. The cause of death might not be covered by the policy, for e.g. behavioural problems and some inherited problems in certain breeds. For example, hip dysplasia (HD) is covered for purebred dogs where the sire and dam are registered with the Swedish Kennel Club (SKK) and have been screened HD-free, but is excluded for mongrels. However, as there are relatively few exclusions for most breeds it may be that most cases of death that do not have a diagnosis (i.e. were not claimed) arise because the owner neglects or chooses not to submit a claim, due to simple omission or, perhaps in some cases, a reluctance to either deal with the issue at a painful time or to benefit financially from the animal's death. For mongrels, life insurance benefits may be quite small. It is likely that for some cases of elective euthanasia (e.g. behaviour problems, owner convenience) a claim would not be submitted.

In a previous study, the agreement between diagnostic data in the database and in the practice records was over 80% in all groups evaluated (*Egenvall et al.* 1998). The overall consistency and accuracy of diagnoses made by practicing veterinarians remains a concern whenever secondary data are used. Consistency is improved by the use of a standard diagnostic registry both within most veterinary practices in Sweden and when data is recorded in the insurance database. Only one diagnosis can be recorded for any case and in general veterinarians are responsible for choosing that designation. Clinicians often use rather non-specific diagnoses, sometimes reflecting the degree to which the case has been resolved (claims may be submitted before final test results are received or owners may elect euthanasia rather than pursue expensive tests to achieve a definitive diagnosis), but often because of time constraints or practical limitations of using the diagnostic registry. For example, one of the most common diagnoses was 'dead – no diagnosis' or similar variants. For the heart system, five diagnoses captured 77% of deaths. However, some of these designations were very non-specific, e.g. 'signs of disease, no cause defined'. In consideration of all these limitations of veterinary diagnoses, both in general and specifically in these insurance data, rather crude diagnostic categories were used, which have been amalgamated over different specific diagnoses, and for which reasonable accuracy can be presumed. Future studies on specific diseases may require further validation of the diagnostic criteria being used by veterinarians.

Overall, among the general diagnostic categories, tumour and trauma had the highest mortality rates (each accounting for almost one fifth of all deaths). Studies of lifetime risk have suggested a wide range in estimates of deaths due to cancer, for example, from 3% of deaths in military working German shepherds (*Peterson et al.* 2000) to 27% of dogs from a German study (*Eichelberg & Seine* 1996) and 16% of all deaths in the UK (*Michell* 1999).

Among all dogs the specific diagnoses with the highest mortality rates were car accident (approximately 21 per 10,000 DYAR), dead-no diagnosis (19 per 10,000 DYAR), epileptic and epileptic-like seizures, hip dysplasia, signs of heart failure and disc herniation. In spite of extensive monitoring of HD among purebred dogs, and given that dogs claimed for HD would be from HD-free parents, this disease still remains a common problem in many breeds.

Road traffic accidents were the cause of death in approximately 0.2% (data not shown) of insured dogs (all breeds) under 10 years of age. This constituted five per cent of all deaths. Sweden is a country with remarkably few stray dogs and these insured dogs are a 'cared-for' population (i.e. receiving veterinary care) yet car accidents are the most common single cause of death. In a survey of owner reported causes of death in the UK, including lifetime deaths, 3% were due to car accidents (*Michell* 1999). Given that younger dogs are more prone to accidental death, age composition may partially explain the higher proportion in this population. However, caution must be used in comparing proportional estimates, as it may be that the actual rate of traumatic death might not be different. True population rates of road traffic accident deaths are not readily available. In general, these findings are in agreement with our previous studies, in spite of some differences in defining diagnostic categories, and using either total deaths (*Egenvall et al.* 2000c) or those with a diagnostic code (*Egenvall et al.* 2000a). As this study incorporates data from six years, these are likely better estimates than the ones previously published. These statistics for traumatic death are important, especially if you consider road traffic accident deaths to be mainly preventable by humans.

Breeds and causes of death

Mortality rates calculated using the exact time at risk are useful for comparison of the occurrence of death between breeds within this population and for comparison with other estimates from the literature. Even breeds with a similar lifespan may have very different age patterns of mortality. Although they must be interpreted carefully, proportional mortality statistics are a useful adjunct to MRs in completing the picture on the pattern of death within various categories. From a population perspective it is interesting to identify those breeds that account for significant proportions of death within that population. For example, German shepherds represent approximately 7% of the total population of insured dogs (in table 1 80,049DYAR/ 1,098,358DYAR=7%), but account for almost 12% of the total mortality. The 10 high-risk breeds account for approximately 5% of the population and 11% of the mortality. If these breeds and German shepherd dogs are combined, the 11 breeds represent 12% of the insured population and account for almost one quarter of all deaths. Several breeds account for a lower proportion of the total mortality, for example golden retrievers constitute 6% of the total DYAR and less than 4% of total deaths.

Heart disease in the Cavalier King Charles spaniel accounts for over 50% of deaths in that breed (in dogs under 10 years of age) and for over one-quarter of the heart deaths in the insured population. Although heart disease in Cavalier King Charles spaniels is well recognized (*Häggström et al.* 1992), these statistics give further insight into the impact of this cause of death in this breed. By comparison, in Irish wolfhounds, although the actual rate of mortality due to heart disease is higher than in the Cavalier King Charles spaniel, that diagnostic category accounts for only 25% of deaths in Irish wolfhounds as they also have other frequent causes of death. Irish wolfhounds represent only 2.7% of all heart deaths in the population, as they as are a less common breed (data not shown). How should these statistics be most effectively used? Mortality rates can be monitored over time to see if there is an increase or decrease in the actual incidence due to, for example, breeding practices. The perception of the commonness of disease occurrence by veterinarians will be a reflection of the population level proportional mortalities, which are also of interest to the insurance company. Proportional mortalities within a breed should inform health strategies among dog breeders, helping them to focus on those diseases causing the most deaths at "too early an age" in their breed.

Notwithstanding the potential usefulness of proportional mortalities, they must be viewed with caution, especially when presented in the absence of actual mortality rates. *Craig* (2001) presents proportional statistics from a necropsy database and concludes that golden retrievers have an increased risk of tumours similar to that for boxers. In this study, the actual rate of tumours in boxers is almost four times higher than that in golden retrievers.

Almost 50% of all deaths in drevers and miniature dachshunds and 37% in dachshunds were due to trauma, although the actual rate in drevers was more than twice that for both types of dachshunds. With these similar proportional mortalities, traumatic death is of similar importance within each breed. However, drevers account for 11% of all deaths due to trauma in the insured population (data not shown) although they are only 3% of all insured dogs. Most drevers and many dachshunds are used in hunting in Sweden and the specific behavioural characteristics for which they are selected also make them prone to roaming. Notwithstanding, the degree to which they die due to traumatic causes is somewhat alarming. The influence of usage on causes of death has been previously reported, for example by *Anderson & Rosenblatt* (1965) who found that field beagles were killed by motor accidents to a very large extent, compared to laboratory beagles that died because of tumours to an overwhelming extent. These findings remind us to be very conscious of the source of data when comparing mortality statistics.

Both the types of trauma and reasons behind an increased risk may vary by breed. Mongrels, miniature and toy poodles and greyhounds also have a high proportional mortality for trauma. For greyhounds, fractures were a common cause of death due to trauma (data not shown). Perhaps smaller dogs may be no more likely to be hit by a car, but may be more likely to die if they are. People may be less likely to pay for expensive veterinary care for mongrels following an accident. Given the human element in traumatic deaths in dogs, these statistics might be considered in discussions relative to responsible pet ownership.

Both Irish wolfhounds and Bernese mountain dogs have approximately 300 deaths due to tumours per 10,000 DYAR in dogs less than 10 years of age. The MR for boxers is 200 per 10,000 DYAR. Within the breed, a dying boxer (under 10 years of age) has a 37% chance that it is due to tumour and a Bernese mountain dog 41%, whereas tumour deaths are 22% of all deaths in Irish wolfhounds. Obviously tumours are an important consideration for these breeds and within the population. *Nielen* (2001) showed a high level of relatedness, inbreeding and litter per sire ratio for Dutch Bernese mountain dogs. Although it is possible to estimate the relative risk for a cause of death by dividing the MR for each breed, it is important to consider other possible factors, such as gender influences and differences in age distribution. Further discussion is presented below, and adjusted estimates of relative risks from multivariable models are presented in the companion paper (*Egenvall et al.* 2005).

An example of the potential for misinterpretation of breed risk based on anecdote can be seen for the neurologic system. Golden retrievers and German shepherd dogs account for 6% and 8% of neurologic deaths so the impression of veterinarians might be that this is a common disease in these breeds. However, that is at least partially due to their frequency in the population. In fact, they do not have a high MR nor an increased risk for death due to neurologic disorders compared to other breeds. The highest incidence is in the St. Bernard, great Dane and boxer. According to the multivariable results (see companion paper, *Egenvall et al.* 2005) these three breeds have a significantly increased risk, whereas Labrador retrievers, and both regular and miniature dachshunds have significantly decreased mortality rates compared to all other breeds.

Gender

In general, for total and diagnostic mortality and for trauma, locomotor, heart and neurological categories, females had a significantly reduced risk of death. In certain breeds and for some causes strong effects were seen. For example male St. Bernards and Bernese mountain dogs were at least 2.5 times more likely to die of neurological causes compared to females (MRR for death = 0.4) and male Newfoundlands and greyhounds were over twice as likely to die of locomotor disorders (MRR for female = 0.5). In many breeds males were significantly more likely to die from heart causes, for example, as much as five times more than females for great Danes.

Although the effect was not significant for all breeds, in general females were at up to two times greater risk of dying from tumours, perhaps not surprising considering the incidence of mammary cancer. However, the notable exception was that among Bernese mountain dogs females were significantly less likely to die with a diagnosis of neoplasia. A further exploration of these differences is presented in the multivariable analysis in the companion paper (*Egenvall et al.* 2005).

Female German shepherd dogs were less likely to die from other diagnoses. Although there were many causes of death in this category, the two most common for that breed were exocrine pancreatic insufficiency and circumanal fistulae (data not shown). An increased risk of males for these conditions has been reported in the literature (*Budsberg et al.* 1985, *Wiberg* 2004).

Improving the health of the population of purebred dogs should be considered not only from a medical perspective but also in terms of animal welfare (*Ott* 1996). In our role as stewards of animal populations, it could be argued that we have a duty to identify and try to reduce preventable disease. These detailed statistics on mortality in various breeds provide a valuable picture of the important causes of death in a large and well-defined population of dogs. To further elucidate the age pattern of death and the relative risk of death across breeds, adjusting for gender and age distribution, multivariable analysis and survival analysis are presented in the companion paper (*Egenvall et al.* 2005).

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Sammanfattning

Mortalitet hos hund baserad på data från över 350 000 svenska hundar försäkrade under 1995 till 2000: 1. Ras-, ålders-, köns- och orsaksspecifika rater.

I denna studie presenteras data från över 350 000 försäkrade svenska hundar, med en ålder upp till 10 år, som tillsammans har bidragit med över en miljon hundår av risk (HÅR) under åren 1995 till 2000. Totalt dog eller avlivades 43 172 hundar. Av dessa hade 72% fått en dödsorsaksdiagnos. Den totala mortaliteten var 393 dödsfall per 10 000 HÅR. Mortalitet uträknades generellt och per dödsorsak för de 10 vanligaste hundraserna, för 10 hundraser med hög mortalitet och för en övrig grupp. Flera typer av proportionell mortalitet presenteras. Fem generella orsaker stod för 62% av alla dödsfall där diagnos förelåg – tumörer (18%), trauma (17%), problem från rörelseapparaten (13%), hjärta (8%) och neurologiska problem (6%). Mortaliteten för de fem vanligaste diagnoserna inom de generella dödsorsakerna presenteras. Denna detaljerade mortalitetsstatistik kan användas både för rasspecifika strategier och för mer generella hälsobefrämjande åtgärder.

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Reprints may be obtained from: A. Egenvall, Department of Clinical Sciences, Faculty of Veterinary Medicine and Animal Science, Swedish University of Agricultural Sciences, SE-750 07 Uppsala, Sweden.