

## Causes of spontaneous death and euthanasia in dogs: A background study in Bahia, Brazil

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**Citation:** Freitas JL, Andrade TS, Martins Filho EF, D'Soares CS, Souza ACSN, Silva AWO, Leal PV, Peixoto TC (2021): Causes of spontaneous death and euthanasia in dogs: A background study in Bahia, Brazil. *Vet Med-Czech* 66, 156–166.

**Abstract:** Understanding the causes of death in dogs enhances the diagnostic capabilities of veterinarians, as well as reduces animal mortality. Studies on this topic assist in the control and prophylaxis of epidemics and in structuring public health programmes. In total, 1 355 necropsy reports of dogs filed at the Veterinary Pathology Laboratory of the Federal University of Bahia, Northeast, Brazil (2005–2017) were analysed. The epidemiological information and anatomopathological diagnoses were obtained. The diagnosed diseases were classified into 10 categories. The frequency of the zoonoses, the overall age of the death (AD) of the dogs, and the AD of the dogs for each disease category were determined. Infectious and parasitic diseases were the most frequent primary causes of death in puppies (44.62%) and adult dogs (26.52%). In elderly dogs, most deaths occurred due to neoplasms (42.37%). Distemper (10.46%) was the most prevalent condition. A high frequency of zoonoses (6.12%) and a high death rate caused by diseases that could have been prevented (15.06%), such as distemper, parvovirus and canine visceral leishmaniasis, were reported. The AD in the population studied was eight years. The results confirmed the hypothesis of a high death rate in dogs in the state of Bahia, Northeast, Brazil, because of preventable infectious diseases.

**Keywords:** age; anatomopathological diagnosis; life expectancy; necropsy

Knowledge of the leading causes of death in dogs enhances the technical skills of veterinarians in diagnosing and treating diseases (Barros 1988). Understanding the cause also enables owners to plan

containment and prophylactic measures to minimise or, at least postpone, the occurrence of a disease (Bonnett et al. 1997; Proschowsky et al. 2003a; Inoue et al. 2015). Thus, we can reduce death rates,

Funded by a fellowship from Fundação de Amparo à Pesquisa no Estado da Bahia (Research Support Foundation of the State of Bahia; No. BOL0586/2019) and by fellowship from Coordenação de Aperfeiçoamento Pessoal de Nível Superior (Brazilian Federal Agency for Support and Evaluation of Graduate Education; finance code 001).

promote longevity (Goldston and Hoskins 1999), and improve the quality of the animals and their owners' lives (Trapp et al. 2010).

Studies on this topic also facilitate the prevention of epidemics (Moore and Lund 2009; O'Neill et al. 2015) and the assessment of the local prevalence of zoonoses. This can generate important data to guide officials in structuring appropriate public health programmes. In addition, retrospective studies on the primary causes of death in dogs are of regional relevance (Figuera et al. 2008). This is especially true in countries with large territorial dimensions such as Brazil, which has distinct epidemiological conditions.

In the last three decades, there has been an increase in the longevity of companion animals and, consequently, a higher incidence of senility-related diseases (Trapp et al. 2010). However, the life expectancy and causes of death in dogs may vary over time. This is due to changes in the popularity and genetic components of each breed, as well as the constant diagnostic and therapeutic advances in veterinary medicine (Lewis et al. 2018), which enables the performance of investigative studies.

Causes of death and euthanasia in dogs have been evaluated in several countries, such as Canada (Olsen and Allen 2000), the United States (Craig 2001), Denmark (Proschowsky et al. 2003b), Sweden (Bonnett et al. 2005), England (O'Neill et al. 2013), Japan (Inoue et al. 2015), Switzerland (Klopfenstein et al. 2016), and Taiwan (Huang et al. 2017). In Brazil, research on this subject is scarce and does not emphasise the prevalence of zoonoses. Moreover, studies have been carried out only in São Paulo, Southeast Brazil (Bentubo et al. 2007) as well as Rio Grande do Sul (RS) (Figuera et al. 2008) and Paraná (Trapp et al. 2010), which are both states in the southern region of the country. In these studies, infectious diseases, such as distemper, parvovirus, and leptospirosis, as well as neoplastic conditions were predominant among the primary causes of death in dogs in Brazil. A higher incidence of infectious diseases in young animals and neoplasms in elderly dogs were reported. No information describing the prevalence of these diseases in the northeast regions is available.

The objective of this study was to determine the frequency of the diseases that culminated in the death or motivated the euthanasia of the dogs at the Federal University of Bahia (Northeast Brazil), encompassing a 13-year period (2005–2017).

## MATERIAL AND METHODS

### Population study and data collection

Dog necropsy protocols, performed from 2005 to the end of 2017 (encompassing 13 years) by the Veterinary Pathology Laboratory (LPV) of the Federal University of Bahia (UFBA), as well as the respective “historical records” completed by the responsible veterinarian or owner of the animal, and additional examination reports, if any, were evaluated.

The majority of the bodies came from the care of the UFBA Veterinary Medicine Hospital (Salvador, Bahia, Northeast Brazil) and, to a lesser extent, from private veterinary clinics in the region. Some bodies were brought by the owners themselves to the LPV for diagnostic elucidation. All the evaluated dogs came from municipalities located in the state of Bahia.

From the necropsy reports, information regarding the necropsy findings and pathological diagnoses were obtained. The evaluated data were compiled and analysed in a manner similar to that of previous studies on the subject, in order to facilitate comparisons.

### Classification of the causes of death

The result of the causes of death of the animals was based on the necropsy findings, associated histories, clinical signs, physical examinations, and supplementary investigations (laboratory, such as blood counts and serum biochemical measurements (alanine aminotransferase, alkaline phosphatase, urea and creatinine), imaging, such as radiographs, ultrasounds and echocardiograms, and histopathology), when necessary. In dogs with more than one disease, the most serious or primary disease was considered to be the cause of death. Cases in which the observed lesions did not justify death (non-specific) were considered as inconclusive.

The cause of death or the euthanasia of the dogs was grouped into the following categories: disorders caused by physical agents, developmental disorders, iatrogenic disorders, degenerative diseases, immune-mediated diseases, infectious and parasitic diseases, metabolic and endocrine diseases, intoxications and toxi-infections (includes poisoning by organophosphates and carbamates,

anticoagulant rodenticide poisoning, acute renal failure methylene blue poisoning, diclofenac poisoning and permethrin poisoning), and neoplasms. Disturbances that could not be classified into any of the previously specified categories were grouped under the heading “others”. Following the classification, the prevalence of death or euthanasia in each group and each condition was calculated in relation to the total number of necropsied dogs.

### Statistical analyses

The animals were categorised based on their age: puppies (aged < 1 year), adult dogs (aged 1–9 years), and elderly dogs (aged ≥ 10 years). The most common disease in each group was evaluated. The limits of each age group were set based on the average of internationally recognised values for each dog size (Goldston and Hoskins 1999) and according to the parameters used in a previous study (Figuera et al. 2008).

The frequencies of death and euthanasia, as well as the primary related diseases were verified in each case. The age of death (AD) of the dogs in the 10 disease categories was determined, and the overall AD was calculated.

Descriptive analyses of the obtained data were performed. Age was the only continuous demographic variable, expressed as the median, interquartile

range (IQR), and range. The Kolmogorov-Smirnov test was used to assess the normality of a single continuous variable, and the binomial proportions test was used to obtain confidence intervals of the percentages. The significance level adopted was  $P < 0.05$ , for a 95% confidence interval, with a two-tailed analysis. The SPSS® v21.0 for Windows statistical program was used for the analyses.

### RESULTS

The cause of death or euthanasia could be determined in 86.79% (1 176/1 355) of the necropsied dogs, and in 13.21% (179/1 355) of the cases, the findings were considered inconclusive. Of the total animals evaluated, 49.96% (677/1 355) died spontaneously, while 48.04% (651/1 355) were euthanised. In 1.99% (27/1 355) of the cases, the type of death was not reported.

Table 1 shows the frequencies of the categories, based on the diagnosed disease of the 1 355 necropsied dogs, as well as the type of death (death or euthanasia).

Infectious and parasitic diseases were the leading cause of death and euthanasia in the dogs (25.65%, 327/1 355), followed by neoplasms (22.58%, 306/1 355) and degenerative diseases (10.85%, 147/1 355). However, when the form of death was revealed, a change was observed in the data (Table 1).

Table 1. Frequencies of the categories according to the diagnosed disease of 1 355 necropsied dogs in Bahia, Northeast Brazil (2005–2017), as well as according to the type of death (death or euthanasia)

Category	Euthanasia		Death		Total	
	N	%	N	%	N	%
Infectious and parasitic diseases	167	25.65	156	23.04	327	24.13
Neoplasms	198	30.41	92	13.59	306	22.58
Degenerative diseases	84	12.90	60	8.86	147	10.85
Disorders caused by physical agents	62	9.52	58	8.57	121	8.93
Poisoning and toxi-infections	10	1.54	78	11.52	88	6.49
Other disorders	19	2.92	49	7.24	70	5.17
Metabolic and endocrine diseases	22	3.38	32	4.73	55	4.06
Iatrogenic disorders	2	0.31	37	5.47	39	2.88
Developmental disorders	7	1.08	13	1.92	20	1.48
Immunomediated diseases	0	0.00	3	0.44	3	0.22
Inconclusive	80	12.29	99	14.62	179	13.21
Total	651	100.00	677	100.00	1 355	100.00

N = absolute value

Infectious and parasitic diseases (24.13%, 327/1 355), distemper (27.83%, 91/327), canine visceral leishmaniasis (CVL); (12.84%, 42/327), leptospirosis (12.54%, 41/327), parvovirus (12.23%, 40/327), and haemoparasite infections (ehrlichiosis and babesiosis) (10.09%, 33/327) were among the most frequent diseases, representing 75.53% (247/327) of the diseases diagnosed in this category. Of the deaths associated with degenerative diseases (10.85%, 147/1 355), almost half of the cases were attributed to chronic kidney diseases (45.58%, 67/147).

Regarding age of the necropsied dogs, 18.52% (251/1 355) were puppies, 36.46% (494/1 355) were adults, and 34.83% (472/1 355) were elderly. In 10.18% (138/1 355) of the cases, the age of the dogs was not reported. Figure 1 shows the primary causes of death in the dogs according to the age group.

Infectious and parasitic diseases were the leading causes of death in puppies (44.62%, 112/251) and adult dogs (26.52%, 131/494). Among the old-

er dogs, most deaths were related to neoplasms (42.37%, 200/472).

The overall AD of the necropsied dogs was eight years. Regarding the distribution of the deaths according to age (Figure 2), it was found that more than 20% of the dogs died before the age of two years, with 10.28% of the deaths in the ages ranging from zero to 11 months. Dogs in the age groups of one to two years (10.53%) and nine to 10 years (7.71%) had the highest death tolls.

The AD of the 10 categories of death and euthanasia are shown in Table 2. Infectious and parasitic diseases, disorders caused by physical agents, and intoxications and toxi-infections accounted for the AD of only three years, in contrast to that observed for degenerative diseases (12 years), neoplasms (11 years), and metabolic and endocrine diseases (10 years).

Figure 3 shows the effect of the age on the frequency of the major causes of death and euthanasia

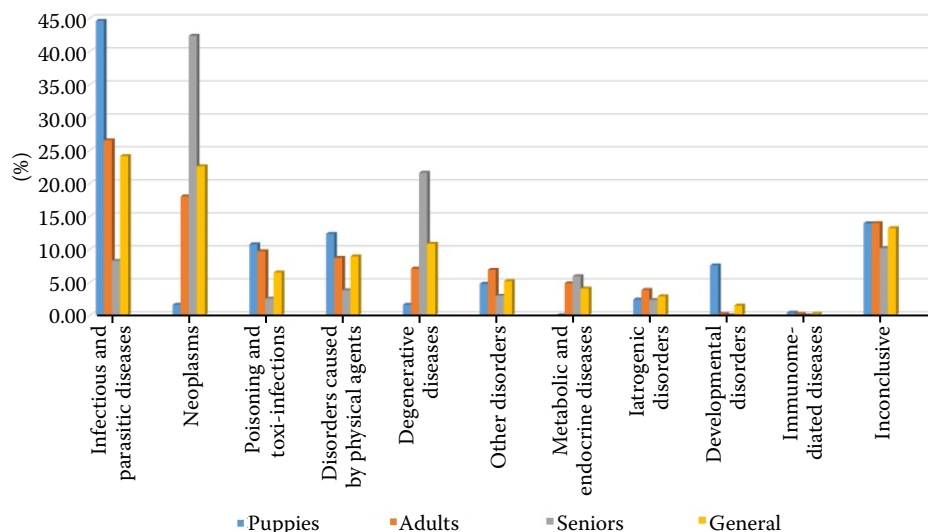


Figure 1. Distribution of the causes of death and euthanasia categories of 1 355 necropsied dogs in Bahia, Northeast Brazil (2005–2017) according to the age group

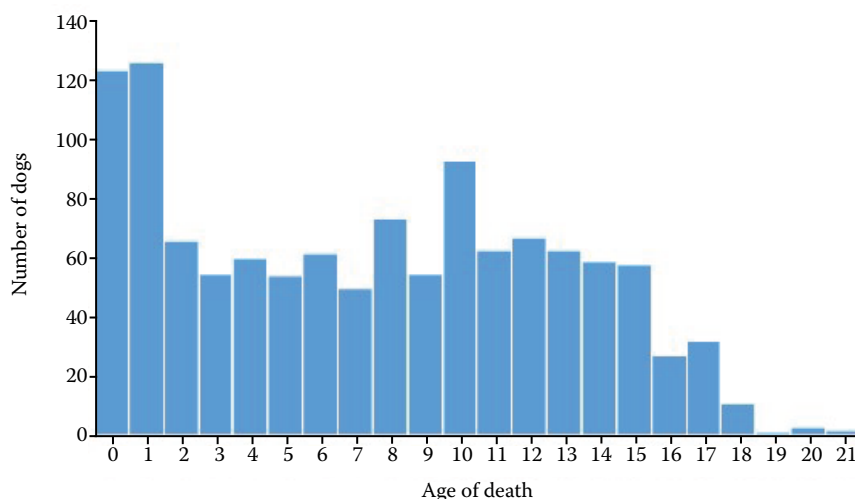


Figure 2. Distribution of the number of deaths of 1 355 autopsied dogs in Bahia, Northeast Brazil (2005–2017) according to the age

<https://doi.org/10.17221/92/2020-VETMED>

Table 2. Classification, absolute value, percentage, confidence interval and age of death of the main categories of causes of death and euthanasia of the necropsied dogs in Bahia, Northeast Brazil (2005–2017)

Categories	Rank	N (%)	CI [95%; (%)]	AD	IQR	Range
Infectious and parasitic diseases	1	327 (24.13%)	21.9–26.5	3.0	0.66–7.0	0.0–18.0
Neoplasms	2	306 (22.58%)	20.4–24.9	11.0	9.0–14.0	0.5–21.0
Degenerative diseases	3	147 (10.85%)	9.3–12.6	12.0	9.0–14.0	0.4–20.0
Disorders caused by physical agents	4	121 (8.93%)	7.5–10.6	3.0	1.0–8.0	0.0–15.0
Poisoning and toxi-infections	5	88 (6.49%)	5.3–7.9	3.0	1.0–7.0	0.1–16.0
Other disorders	6	70 (5.17%)	4.1–6.5	5.5	2.0–9.0	0.0–17.0
Metabolic and endocrine diseases	7	55 (4.06%)	3.1–5.2	10.0	6.0–12.0	2.0–17.0
Iatrogenic disorders	8	39 (2.88%)	2.1–3.9	5.0	3.0–10.0	0.2–14.0
Developmental disorders	9	20 (1.48%)	0.9–2.3	0.04	0.0–0.22	0.0–2.0
Immunomediated diseases	10	3 (0.22%)	0.08–0.65	4.08	*	0.2–8.0

AD = age of the death; CI = confidence interval; IQR = interquartile range; N = absolute value

\*Interquartile range cannot be calculated due to reduced number of observations; 95% confidence interval (95% CI) calculated for proportions

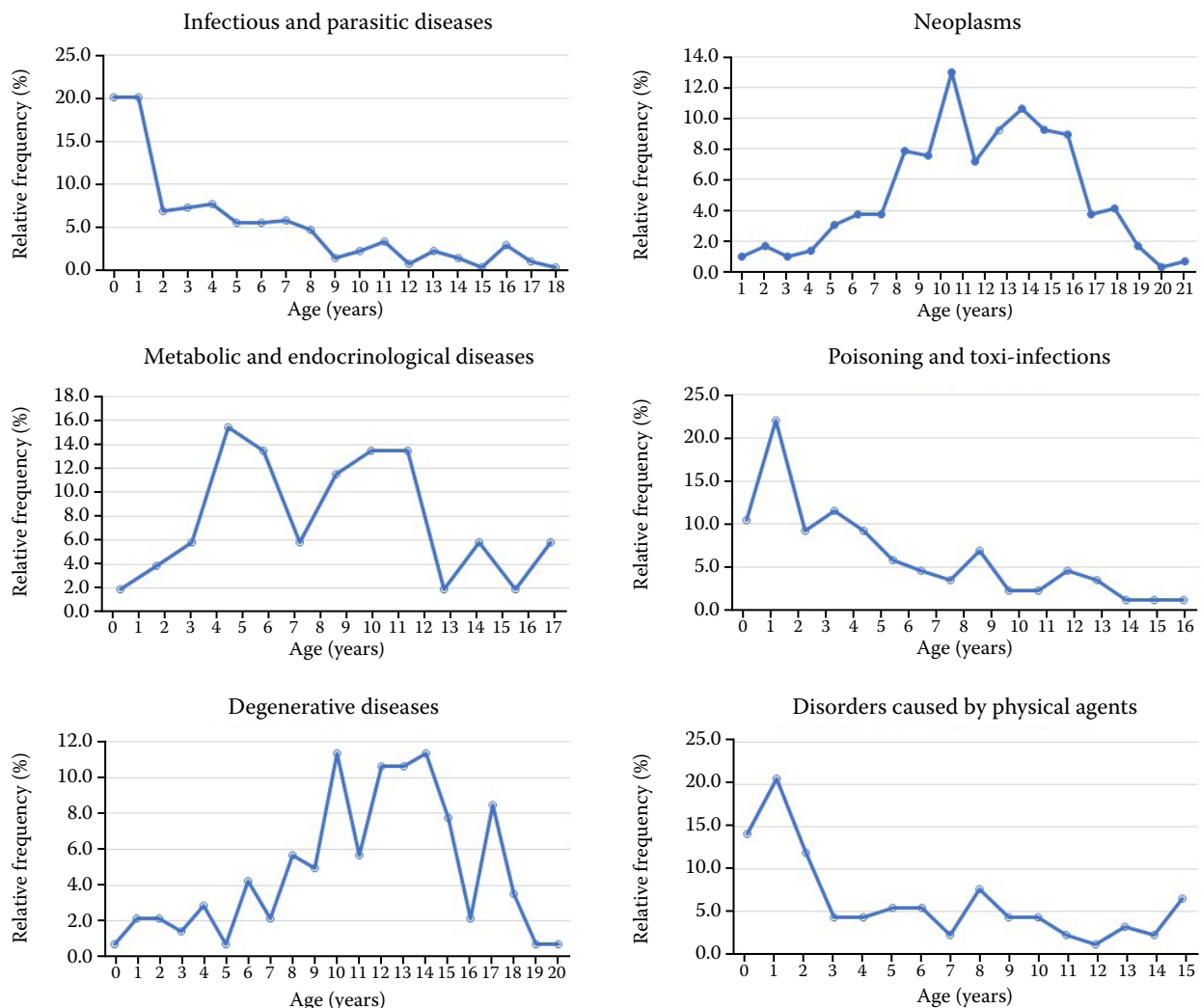


Figure 3. Relative frequency of the cause of death categories according to the age of the death of the 1 355 necropsied dogs in Bahia, Northeast Brazil (2005–2017)



in the necropsied dogs. When analysing the diseases, regardless of the classification, 105 nosological entities (excluding neoplasms) were identified. The main diseases responsible for the spontaneous death or euthanasia of the dogs were as follows: distemper (10.46%), CKD (7.7%), run-over polytrauma (5.98%), pyometra (5.29%), carbamate poisoning (5.06%), canine visceral leishmaniasis (CVL) (4.8%), leptospirosis (4.71%), and parvovirus (4.60%).

## DISCUSSION

In the present study, in 86.79% of the necropsied dogs, the cause of death could be determined, while in 13.21% of the cases, the diagnoses were considered inconclusive. In a study conducted in Paraná (southern region of Brazil), the frequency of inconclusive diagnoses was 8.6% (Trapp et al. 2010), while in Santa Maria-RS (southern region of Brazil), a value approximately three times higher (32%) (Figuera et al. 2008) than that of the present study was observed. The occurrence of inconclusive necropsies was to be expected and was associated with macroscopic limits, such as certain diseases have no detectable morphological alterations (Maranhao and Marlet 1987). Moreover, in some cases, there was insufficient or a lack of clinical information in order to arrive at a diagnostic conclusion (Ferreira et al. 2018).

The euthanasia index observed was 48%. In other countries, the frequency of euthanasia varied from 21.8% in Taiwan (Huang et al. 2017), 79.58% in the United Kingdom (Lewis et al. 2018), 85.2% in the United States (Moore et al. 2001), and 86.4% in England (O'Neill et al. 2013); however, no national data were found on the frequency of euthanasia in dogs in Brazil. The poor prognosis in dogs suffering from diseases may justify euthanasia; however, the ethical issues and emotional conflicts involved in these situations are predictive during decision-making (Davis et al. 2003; Yeates and Main 2011). Therefore, the frequency of dogs submitted to euthanasia may reflect the opinion of the owners and veterinarians regarding the prioritisation of the quality of life over the longevity of the animal (O'Neill et al. 2013).

When analysing the causes of death according to the age, a higher prevalence of spontaneous deaths was observed among adult dogs (36.46%). A higher death rate of adult dogs (48.6%) was also

described in the study conducted in Santa Maria-RS (Figuera et al. 2008). However, in the other categories, the death rate of puppies was approximately twice as high (39%) and that of elderly dogs was approximately three times lower (12.4%) than that in puppies. Considering the chronological variations of the studies, this difference can be attributed to the increased life expectancy of dogs in recent years. This reflects the change in the behaviour of owners regarding the health of their animals (Trapp et al. 2010).

The higher incidence of deaths caused by infectious and parasitic diseases in puppies and adult dogs is similar to that described in the study conducted in Paraná (Trapp et al. 2010). However, in the present study, the puppy involvement was approximately twice as high as adult dogs, mainly due to the high rate of distemper and parvovirus infections in animals of less than one year of age (27.9%, 70/251). However, the high frequency of neoplasms in elderly dogs explains the prominence of this category among the euthanised animals (30.41%, 198/651) (Table 1).

Distemper, which stood out as the leading cause of death and euthanasia in dogs in this study, was also the disease most frequently associated with a dog's death in the study conducted in Rio Grande do Sul (12.4%) (Figuera et al. 2008). These data show that although this disease has been described since 1746 (Panigassi and Maiorka 2017) and has a well-established vaccine, prophylaxis (Day et al. 2016), it has a great impact on the canine population in different regions of Brazil, especially due to the absence of an effective therapeutic protocol (Kajita et al. 2006; Portela et al. 2017).

Although a rabies vaccination is essential (Day et al. 2016) and free (Municipal Health Secretariat of Salvador 2019), according to the Pesquisa Nacional de Saúde [(PNS) National Health Survey] carried out by the Brazilian Institute of Geography and Statistics, [Instituto Brasileiro de Geografia e Estatística (IBGE)] in 2013, about 30% of dogs and cats domiciled in the Northeast region had not received a rabies vaccine in the previous 12 months (IBGE 2015). Thus, it can be inferred that, when it comes to the multipurpose vaccine, which protects against distemper and parvovirus, and is considered elective and not free, the rate of adherence to vaccination is lower. It is evident, therefore, that the veterinarian must act as a health promoting agent, through the guidance of owners on the im-

portance of vaccination, as well as the need for investment in public awareness campaigns aimed at reducing the mortality of dogs in the country.

The second most frequent infectious disease in this study was canine visceral leishmaniasis (CVL) [12.84% (42/327)]. It is known that CVL is a zoonosis occurring in Asia, Europe, the Middle East, Africa and the Americas. It has been described in at least 12 countries in Latin America, with 90% of the cases occurring in Brazil, especially in the Northeast region. Between 1984 and 2002, 48 455 cases of the disease were reported in humans, approximately 66% in the states of Bahia, Ceará, Maranhão and Piauí (Ministry of Health 2014). The highlight of CVL among the main infectious causes of death in the dogs demonstrated here, in epidemiological terms, reinforces the inclusion of the State of Bahia as an endemic area for the disease.

According to the Manual for surveillance and control of visceral leishmaniasis by Ministry of Health (Manual de vigilância e controle da leishmaniose do Brasil, Ministério da Saúde), the administration of vaccines and the use of collars impregnated with deltamethrin are not yet designated as prophylactic methods in public health programmes. This is due to the lack of proven effectiveness (Ministry of Health 2014). In fact, it has already been demonstrated that the efficacy of an immunoprophylaxis through vaccination, in dogs that live outside in endemic areas, is not adequate (Fernandes et al. 2014; Grimaldi et al. 2017).

On the other hand, recent studies have shown that collars impregnated with deltamethrin, when used correctly, are effective in reducing the CVL infection. These studies suggest that the large-scale use of deltamethrin as a disease control strategy has the possibility of good medium- to long-term results (Coura-Vital et al. 2018; Leite et al. 2018; Paulin et al. 2018).

Notably, although CVL was the second most common infectious disease (42/327, 12.84%), it was not mentioned in the retrospective studies conducted in Santa Maria-RS (Figuera et al. 2008), Paraná (Trapp et al. 2010) (both from the southern region of Brazil); and São Paulo (Bentubo et al. 2007) (the southeast region of Brazil). It should be considered that Rio Grande do Sul (RS) and Paraná, at the time of the study, were areas free of CVL, and the first indigenous cases were observed in 2008 and 2009 in RS (Tartarotti et al. 2011) and Paraná (Thomaz-Soccol et al. 2009), respectively. However, although

CVL has not been listed among the causes of death of dogs in São Paulo (Bentubo et al. 2007), there have been records of this disease in the dogs in this region since the 1990s (Scandar et al. 2011). Such contrasting data highlights the regional epidemiological differences and emphasises the relevance of retrospective studies in the different states and regions of Brazil.

The high occurrence of infectious and parasitic diseases (24.13%, 327/1 355) described here emphasises the impact of these diseases in reducing the life expectancy of the dogs in the area covered by this study. Similar data were shown in the studies conducted in other provinces of Brazil, Santa Maria-RS (35%) (Figuera et al. 2008), Paraná (42.27%) (Trapp et al. 2010) and São Paulo (35.11%) (Bentubo et al. 2007).

It is noteworthy that CVL (12.84%) and leptospirosis (12.54%), considered potentially zoonotic diseases, represented 25.38% of the infectious and parasitic diseases and 6.12% (83/1 355) of the total number of nosological entities. Data of this nature were non-existent in Brazil, as the scant research found on the causes of death in dogs did not emphasise the prevalence of zoonoses (Bentubo et al. 2007; Figuera et al. 2008; Trapp et al. 2010). Knowledge of this prevalence is fundamental for the adoption of preventive public health measures in Northeast Brazil.

In addition, distemper and parvovirus, diseases caused by viral agents, accounted for 40.06% (131/327) of the infectious conditions, and seemed preventable by vaccination. These data show that the immunisation of dogs from the state of Bahia (northeast region of Brazil) has not been achieved yet, and is similar to that in Santa Maria-RS (Figuera et al. 2008), and Paraná (Trapp et al. 2010).

Neoplasms were the second leading cause of death in the necropsied dogs in Bahia, accounting for 22.58% (306/1 355) of the total diagnoses. However, in elderly animals, neoplasms stood out as the main cause (42.37%, 200/472) of the dog's deaths, which confirms the correlation between the increased cases of cancer and life expectancy of the population of dogs and cats (Craig 2001; Bonnett et al. 2005; Figuera et al. 2008).

In addition, the increased demand from owners for veterinary health care services associated with better management practices and the adoption of preventive health measures, in general, tends to promote the longevity of companion animals.

Consequently, a higher prevalence of neoplasms, commonly associated with older animals (Kitchell 1999; Mazzatenta et al. 2017) is observed. Another aspect to be considered is that the close relationship between humans and pets results in exposure to the same risk factors for cancer, such as lifestyle, diet, and environmental pollution (Zaidan Dagli 2008; Mazzatenta et al. 2017). This may also have influenced the high frequency of diagnosed neoplasms in older dogs.

Although neoplasms were not specified, it was observed that among the dogs evaluated, there was a high rate of neoplasms in the mammary glands, in part, with metastatic dissemination. The high frequency of breast tumours in dogs, the most frequent neoplasm, corresponding to approximately 50% of the total neoplasms found in females, is already known (Toribio et al. 2012). Previous studies show that among neoplasms, breast carcinoma represents one of the most important ones in cancer care in canine clinics (Pires et al. 2003; Furian et al. 2007; Kim et al. 2018). In some surveys on the causes of death and reasons for the euthanasia, mammary gland neoplasms were the most prevalent diagnoses (Bonnett et al. 2005; Figuera et al. 2008; Trapp et al. 2010). According to a consensus on the diagnosis, prognosis and treatment of canine breast tumours, sterilisation (considered one of the best ways to prevent breast cancer in female dogs), should be performed between the first and the second oestrus, when the main objective is the prevention of breast cancer and not population control (Cassali et al. 2017).

Degenerative diseases were the third most common category evaluated and included 147 (10.85%) cases. Of these, 45.58% (67/147) were due to chronic kidney disease (CKD). In fact, CKD occurs most frequently in adult elderly dogs and cats and is considered the third most common cause of a dog's death (Chew et al. 2011). Most dogs with advanced stages of CKD in later stages die or are euthanised within two years (Polzin 2013).

The prevalence of senility-related changes, including degenerative diseases, is 20.8% in Denmark (Proschowsky et al. 2003b), 39% in England (O'Neill et al. 2013), and 67.2% in the United States (Moore et al. 2001), which is different from that observed in the present study (10.85%), as well as in other studies conducted in Brazil. In Brazil, prevalence rates of 5.57%, 7.1%, and 8.63% were recorded in São Paulo (Bentubo et al. 2007), Santa

Maria-RS (Figuera et al. 2008), and Paraná (Trapp et al. 2010), respectively. This difference probably reflects a disease prevention culture, which is well established in Europe and the United States, but remains precarious in Brazil.

The overall AD found in this study (eight years) was lower than the life expectancy of dogs from the United Kingdom [11.3 years; Adams et al. (2010)], the United States [10.28 years; Moore et al. (2001)], Denmark [10 years; Proschowsky et al. (2003b)], Taiwan [10.2 years; Huang et al. (2017)], and Japan [13.7 years; Inoue et al. (2015)]. However, dogs from Bahia, Northeast Brazil, had a higher longevity when compared to dogs from other Brazilian states, such as São Paulo (southeast region of Brazil); [3 years; Bentubo et al. (2007)] and Paraná (south region of Brazil); [5 years; Trapp et al. (2010)]. The low life expectancy of dogs in Brazil has been related to the high prevalence of infectious and parasitic diseases (Trapp et al. 2010). It is believed that deaths due to infections reflect a lack of knowledge and negligence of the owners and may be affected by socio-economic aspects (Bentubo et al. 2007). Therefore, these findings may serve as guiding criteria in the implementation of mortality control programmes, such as immunoprophylaxis.

The analysis of the distribution of animal deaths according to the age of occurrence corroborates to previously demonstrated data, wherein high death rates were observed in the first year of life, with a subsequent reduction after three years of age and a further elevation from the age of seven years (Michell 1999; Adams et al. 2010; Trapp et al. 2010; O'Neill et al. 2013; Huang et al. 2017; Lewis et al. 2018). It is likely that the high rate of mortality in puppies (aged zero to 11 months) contributed to the reduced life expectancy of the dogs.

Infectious and parasitic diseases, aside from being the main cause of death in the dogs (24.13%), were also responsible for a reduced AD (three years). It is worth mentioning that, in the state of São Paulo, infectious and parasitic diseases further lowered the AD, by 12 and 8 months on average, respectively (Bentubo et al. 2007). This emphasises the importance of the control and prophylaxis of these diseases in large urban centres. In Taiwan, dogs with infectious diseases had the fifth lowest AD (six years) (Huang et al. 2017), which may be associated with the adoption of more effective prophylactic measures in this country (Moore et al. 2001).



In the necropsied animals in Bahia, the average age of death due to degenerative diseases (12 years), neoplasms (11 years), and metabolic and endocrine diseases (10 years) were the highest, corroborating previous studies (Bentubo et al. 2007; Huang et al. 2017). However, in São Paulo, neoplasms and metabolic diseases, although representing the second and fourth highest causes of death, showed lower values (seven and four years, respectively) (Bentubo et al. 2007) than those found in the present study. Further studies identifying the mean AD of dogs due to different reasons in other regions of the country are necessary to clarify the observed divergences, as well as to determine values that are more accurate.

The analysis of the effect of the age on the frequency of the causes of death and euthanasia (Figure 3) underlies and reinforces the findings demonstrated and discussed earlier.

In this 13-year study (2005–2017), distemper was the most common reason of death (disease observed) in the dogs. Infectious and parasitic diseases were the main causes of death in puppies and adult dogs, while neoplasms stood out among elderly dogs, which confirms the correlation between the age and causes of death. The data obtained confirm the hypothesis that a high number of deaths in dogs in the state of Bahia are caused by diseases that can be prevented, especially by vaccination (distemper and parvovirus) or by using collars impregnated with deltamethrin (for CVL). It was also confirmed that the high frequency of zoonotic diseases was a cause of death in the dogs in the evaluated region. These data have relevance for public health initiatives considering the increasing interaction between humans and dogs.

The overall average age of death observed in the studied population was eight years and higher in dogs with degenerative diseases. Such assessments assist in determining the impact of health conditions on the life expectancy of dogs. The data obtained in this study will contribute to the establishment of differential diagnoses, adoption of prophylactic measures, guidance to the owners, and training of veterinarians, especially in the state of Bahia, Northeast Brazil.

### Conflict of interest

The authors declare no conflict of interest.

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Received: April 22, 2020

Accepted: December 11, 2020