



Causes of shelter cats mortality in the Czech Republic

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ABSTRACT

Awareness of the causes of mortality in shelter cats can contribute to its effective reduction. The aim of this study was to investigate the causes of mortality in cat shelters in the Czech Republic, taking into account the age of the animals and their length of stay in the shelter facilities until natural death or euthanasia. A cooperation with two private no-kill shelters in the Czech Republic was established. The subject of the study were records of 3047 cats admitted to the selected shelters in the period from 2013 to 2023. A total of 357 (11.7 %) out of 3047 cats died or had to be euthanized in two monitored shelters. No significant difference ($p > 0.05$) in the cat mortality was found between the two shelters (11.5 % and 12 %). The median length of stay of cats in the shelter until death or euthanasia was 23 days. The highest mortality was recorded in the youngest cats (≤ 6 months). The most common causes of death or euthanasia of cats in both shelters were feline infectious peritonitis (21.6 %), pancytopenia (18.5 %) and upper and lower respiratory tract infections (17.5 %). Adult and older cats were significantly ($p < 0.05$) more prone to death due to renal failure and cancer than young animals and kittens. The results of the study contribute to the knowledge on the health of cat population in shelters in the Czech Republic and can serve as a basis for further work that will target mortality reduction strategies in at-risk categories.

1. Introduction

Millions of animals are admitted to cat shelters worldwide every year and thousands of them die or are euthanized there. Poor cat health is a common reason for death or euthanasia, however, in many shelters, animals are also due to overpopulation, their low adoption potential or behavioural issues. From animal welfare perspective, it is desirable to reduce the number of unnecessary animal deaths and to introduce interventions increasing cat adoptions. Consequently, some countries (e.g. Italy, Austria, Greece) (Barnard et al., 2016; Arhant & Troxler, 2017) have adopted a so-called no-kill policy, i.e. a policy allowing the euthanasia of an animal only for health and behavioural reasons (e.g. the animal poses a risk to public safety). In the Czech Republic, a strict no-kill policy was implemented. According to the national legislation, the euthanasia of an animal is only allowed for health reasons. Problem behaviour is not a legitimate reason to kill any animal (Act No. 246/1992 Coll., on the protection of animals against cruelty, as amended). The general rule in case of no-kill policies is to keep euthanasia rates below 10 %, as the percentage of animals in the population that suffer from an intractable health problems or behavioural problems that makes them unadoptable is usually not beyond this limit Best Friends

(2023).

The issue of shelter cat mortality in the Czech Republic was previously addressed by Večerek et al. (2017). They monitored three Czech shelters in which a total of 474 cats died during a five-year monitoring period and another 240 had to be euthanized for various health reasons. Thus, despite the care provided, death was an ultimate outcome for 33 % of cats admitted to the monitored shelters. The results of the study showed that 67.3 % of the animals died within the first month of admission to the shelter and 95.4 % of the cats died within the first 6 months Večerek et al. (2017). Euthanasia was performed on 65 % of cats within the first month, 88.3 % of all euthanasia was performed within 6 months of admission. In the more recent study (Vojtkovská et al., 2019) in which a population of dogs and cats in the Czech shelters was monitored, a cat mortality rate of 2.8 % was reported. In Europe, data on intakes and outcomes for shelter cats were also published by van der Leij et al. (2023) in the Netherlands. In Dutch shelters, 9.5 % of cats were euthanized or died in the period from 2006 to 2021. In Belgium, a 27 % mortality rate of shelter cats was reported Leefmilieu.brussel (2019). In Austria, the number of cats euthanized in a shelter ranged from 5 to 10 % Arhant et al. (2011). In Sweden, less than 10 % of shelter cats was euthanized in 2006 Eriksson et al. (2009).

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The finding that a large number of deaths occur in the Czech shelters shortly after admission of cats was explained by (Večerek et al., 2017) by the fact that a significant number of animals were likely admitted to the shelters in poor health. (Večerek et al., 2017) did not consider the health issues and subsequent mortality as a result of, for example, high infectious pressure in the shelter environment caused by poor shelter management. Deterioration of health of cats during their stay in the shelter has been previously confirmed via monitoring of health-based welfare indicators by Vojtkovská et al. (2021). Preventing the entry of pathogens into the shelter environment with respect to a dynamically changing population is a rather complex task, yet shelters can largely prevent the transmission of infections between animals by appropriate layout of the premises and the implementation of proper quarantine, isolation, sanitation and preventive veterinary care procedures. Upper and lower respiratory tract diseases and various gastrointestinal problems are typical for shelter cats Pesavento & Murphy (2014); Vojtkovská et al. (2022a). An important factor contributing to the development and reactivation of diseases is stress Amat et al. (2016).

Despite significant number of cats dying in the no-kill shelters in the Czech Republic, causes of mortality have been little studied. Since there is no national database regarding the mortality of cats in shelters in the Czech Republic, we selected two cat shelters for the purposes of this study. We investigated the causes of death of cats in these facilities, taking into account the age of the animals and their length of stay (LOS) in the shelter until death or euthanasia.

2. Materials and methods

In order to obtain data, a cooperation with two private shelters in the Czech Republic was established. These shelters were selected on the basis of similarity in management - animals were group-housed in both facilities, had an outdoor fenced area at their disposal and almost identical amount of space provided (Shelter A provides 2.3 m² per animal, Shelter B 2.1 m²). After admission, the animals in both facilities are placed in quarantine boxes, the length of the quarantine period depends on the health status of the individual. During the quarantine period, a basic examination by a veterinarian is carried out, followed by standard preventive procedures (vaccination, removal of ecto and endoparasites, FIV and FeLV status testing, microchipping). In both shelters, each admitted animal is routinely neutered if it permits its health condition and if the circumstances indicate that the individual is not owned. Neither shelter has its own veterinary facility, therefore, the animals are transported to a contracted veterinary clinic to perform procedures. In Shelter A, the care is provided by 1 caretaker and 3 volunteers, Shelter B is operated by 1 permanent caretaker and 1 volunteer who comes to the shelter when needed. Both shelters use dry, pelleted food in super-premium quality to feed the animals, supplemented with wet, canned food. In both shelters, food and water bowls are shared by several animals, dry food and water are available to the animals ad libitum. The housing areas for cats include enrichment in the form of toys, cat trees, and other equipment enabling animals to climb, rest or hide. There are 32 open and enclosed cat toilets in Shelter A, and 8 ones in Shelter B (one cat toilet per approximately 3 cats in both shelters). Toilets are cleaned daily or more often if needed. Other areas are cleaned daily using common disinfectants.

The subject of the study were data provided by operators of both shelters containing information on cat mortality and its causes. The analysis included data on all animals admitted to Shelter A from January 1, 2013 – November 24, 2019 and to Shelter B from January 1, 2013 – November 27, 2023 that completed their stay at the facilities during the monitored period. The database from which the data were collected contained also information on sex of the animals, their exact or estimated age, date of admission to the shelter, their outcome and in case of death also date and the cause of natural death or euthanasia. For the analysis of the effect of age, animals were divided into four age categories (kittens: ≤ 6 months, young cats: $6 < x \leq 12$ months, adult cats: 1

$< x \leq 8$ years, older cats: > 8 years).

The statistical program Unistat 6.5 for Excel (Unistat Ltd., UK) was used for data processing. To analyse differences in the numbers of animals in the categories created (cause of death or euthanasia), the χ^2 test was used. Kruskal-Wallis ANOVA was used to analyse differences in LOS (length of stay) in the shelter for individual causes of mortality and euthanasia and between age categories. Kruskal-Wallis ANOVA was followed by a non-parametric Tukey - type test as a post hoc test for pairwise comparisons between comparison groups. The Mann-Whitney U test was used to observe differences in the LOS of cats in Shelter A and Shelter B until death and euthanasia, respectively. A p value ≤ 0.05 was considered statistically significant.

3. Results

During the monitored period, 1806 cats were admitted to Shelter A. The outcome for 208 (11.5 %) of cats was death or euthanasia, namely 173 (83.2 %) cats died and 35 (16.8 %) cats were euthanized. The median LOS of cats in Shelter A until death or euthanasia was 19 days (mean 107 days, min. 0 days, max. 1827 days). The median LOS until death was 17.5 days (mean 107.59 days); the median LOS until euthanasia was 26 days (mean 104.3 days). Reasons for euthanasia included feline infectious peritonitis (FIP, $n=5$), unknown cause (reason not listed in database, $n=5$), injury ($n=4$), FeLV ($n=2$), FIV ($n=2$), tumours ($n=3$), renal failure ($n=3$), lung disease ($n=2$), neurological problems ($n=2$), old age ($n=2$), FPV ($n=1$), intractable problems with defecation ($n=1$), fading kitten syndrome ($n=1$), fluid in abdominal and thoracic cavity of unknown cause ($n=1$).

The highest mortality (127, 61.1 %) was recorded in the youngest cats (≤ 6 months) (Table 1), a significant difference between the mortality rates of cats in different age categories was found except for the difference between young cats and older cats ($p=0.7089$) (Table 2). The LOS of cats until death or euthanasia did not differ significantly between age categories (Table 3).

A total of 1241 cats were admitted to Shelter B during the monitored period, out of them 149 (12 %) cats died or were euthanized. The numbers of animals that died and the numbers of animals that were euthanized are unknown, as Shelter B did not distinguish natural death and euthanasia in their records. The median LOS of cats in the shelter until death/euthanasia was 28 days (mean 62.5 days, min. 1 day, max. 1222 days). Similar to Shelter A, the highest mortality was observed in the youngest cats (Table 1). A significant difference between the mortality of cats in different age categories was found except for the difference between young cats and older cats ($p=0.3429$) (Table 4). The LOS of cats in the shelter until death/euthanasia did not differ significantly between age categories (Table 5).

In total, 357 (11.7 %) out of 3047 cats admitted to Shelter A and B in the monitored period died or were euthanized. No significant difference ($p=0.7138$) was found between the number of cats that died or were euthanized in shelters A and B (208 and 149, respectively). The median LOS of cats in the shelter until death or euthanasia was 23 days (mean 88.6 days, min. 0 days, max. 1827 days). Significant difference ($p=0.0194$) was found between the LOS of cats in Shelter A and Shelter B until death or euthanasia (19 and 28 days, respectively). In general, the highest mortality was recorded in the youngest cats (Table 1). The mortality of cats differed significantly between age categories except for the difference found between young cats and older cats ($p=0.8834$) (Table 6). The LOS of cats in the shelter until death/euthanasia did not differ statistically between age categories (Table 7).

Out of 357 cats that died or were euthanized in Shelter A and B, the cause of death or euthanasia was known in 292 cases. Based on the cause of death or euthanasia, 16 categories were established (Table 8). The most frequent causes of death or euthanasia were FIP, panleukopenia, and upper and lower respiratory tract infections. The numbers of dead or euthanized cats in these three causes were not significantly different ($p=0.4377$). A significant difference ($p=0.0008$) was found when

Table 1
Comparison of mortality rates and LOS (length of stay) in shelters A and B in four age categories.

age category	Shelter A		Shelter B		Shelter A + B	
	n (%)	median LOS until death or euthanasia (days)	n (%)	median LOS until death or euthanasia (days)	n (%)	median LOS until death or euthanasia (days)
≤ 6 months	127 (61.1 %)	18	103 (69.1 %)	28	230 (64.4%)	21.5
6 < x ≤ 12 months	17 (8.2 %)	13	7 (7.0 %)	21	24 (6.7%)	17.5
1 < x ≤ 8 years	50 (24 %)	23.5	27 (18.1 %)	43	77 (21.6%)	25
> 8 years	14 (6.7 %)	18.5	12 (8.1 %)	22	26 (7.3%)	20

Table 2
The pairwise comparisons (p-values) of mortality rates in the four age categories of cats in the shelter A.

	≤ 6 months	6 < x ≤ 12 months	1 < x ≤ 8 years	> 8 years
≤ 6 months	-	0.0000	0.0000	0.0000
6 < x ≤ 12 months	-	-	0.0000	0.7089
1 < x ≤ 8 years	-	-	-	0.0000
> 8 years	-	-	-	-

Table 3
The pairwise comparisons (p-values) of LOS of four age categories of cats in the shelter A.

	≤ 6 months	6 < x ≤ 12 months	1 < x ≤ 8 years	> 8 years
≤ 6 months	-	0.1969	0.3256	0.9936
6 < x ≤ 12 months	-	-	0.0771	0.3520
1 < x ≤ 8 years	-	-	-	0.5922
> 8 years	-	-	-	-

Table 4
The pairwise comparisons (p-values) of mortality rates in the four age categories of cats in the shelter B.

	≤ 6 months	6 < x ≤ 12 months	1 < x ≤ 8 years	> 8 years
≤ 6 months	-	0.0000	0.0000	0.0000
6 < x ≤ 12 months	-	-	0.0005	0.3429
1 < x ≤ 8 years	-	-	-	0.0162
> 8 years	-	-	-	-

Table 5
The pairwise comparisons (p-values) of LOS of four age categories of cats in the shelter B.

	≤ 6 months	6 < x ≤ 12 months	1 < x ≤ 8 years	> 8 years
≤ 6 months	-	0.9076	0.3261	0.5746
6 < x ≤ 12 months	-	-	0.5425	0.7909
1 < x ≤ 8 years	-	-	-	0.2687
> 8 years	-	-	-	-

comparing the numbers of cats that died or were euthanized due to FIP, panleukopenia, and upper respiratory tract infections with numbers of cats dying or being euthanized for other reasons.

Cats that died or were euthanized due to FIP stayed in the shelter significantly longer than cats that died or were euthanized due to panleukopenia ($p = 0.00001$) and upper and lower respiratory tract

Table 6
The pairwise comparisons (p-values) of mortality rates in the four age categories of cats in the shelter A and B.

	≤ 6 months	6 < x ≤ 12 months	1 < x ≤ 8 years	> 8 years
≤ 6 months	-	0.0000	0.0000	0.0000
6 < x ≤ 12 months	-	-	0.0000	0.8834
1 < x ≤ 8 years	-	-	-	0.0000
> 8 years	-	-	-	-

Table 7
The pairwise comparisons (p-values) of LOS of four age categories of cats in the shelter A and B.

	≤ 6 months	6 < x ≤ 12 months	1 < x ≤ 8 years	> 8 years
≤ 6 months	-	0.2292	0.1928	0.9351
6 < x ≤ 12 months	-	-	0.0664	0.3940
1 < x ≤ 8 years	-	-	-	0.4056
> 8 years	-	-	-	-

infections ($p = 0.00001$). Cats that died or were euthanized due to panleukopenia did not stay in the shelter significantly longer ($p = 0.1839$) than cats that died or were euthanized due to upper and lower respiratory tract infections.

The numbers of cats that died or were euthanized due to FIP differed significantly ($p = 0.0003$) between shelters. Significantly higher number of cats died or were euthanized due to FIP in Shelter B. Upper and lower respiratory tract infections significantly ($p = 0.0002$) more often led to death/euthanasia in Shelter B. In contrast, gastrointestinal problems resulted in death/euthanasia significantly ($p = 0.0045$) more frequently in Shelter A. No significant difference ($p = 0.6450$) was found in the numbers of cats that died or were euthanized due to panleukopenia in Shelter A and Shelter B. No significant differences were found when comparing LOS of cats in Shelter A and Shelter B until death or euthanasia due to FIP ($p = 0.1317$), panleukopenia ($p = 0.3281$) and upper and lower respiratory tract infections ($p = 0.9110$).

Table 9 presents the numbers and LOS in the shelter of cats in different age categories depending on the cause of death or euthanasia. Significantly more cats younger than 6 months died or were euthanized due to FIP ($p = 0.00001$), panleukopenia ($p = 0.00001$) and upper and lower respiratory tract infections ($p = 0.00001$) when compared with other age categories. Significantly more adult and elderly cats died due to renal failure ($p = 0.00001$) and tumours ($p = 0.0009$) than young cats and kittens.

4. Discussion

The Czech Republic is one of the countries that have implemented a no-kill policy in animal shelters, which is reflected in the results of this

Table 8

Number of cats and their LOS (length of stay) in the shelter until death/euthanasia depending on the cause.

cause of death/euthanasia	Shelter A		Shelter B		Shelter A + B	
	n (%)	median LOS (days)	n (%)	median LOS (days)	n (%)	median LOS (days)
feline infectious peritonitis (FIP)	24 (15.4)	120	39 (28.7)	74	63 (21.6)	83
panleukopenia (FPV)	33 (21.2)	24.5	21 (15.4)	14	54 (18.5)	16
upper and lower respiratory tract infections	16 (10.3)	23	35 (25.7)	16	51 (17.5)	18
gastrointestinal problems	17 (10.9)	16	2 (1.5)	18.5	19 (6.5)	16
renal failure	12 (7.7)	16.5	5 (3.7)	20	17 (5.8)	18
fading kitten syndrome	9 (5.8)	12	8 (5.9)	20	17 (5.8)	12
other causes*	7 (4.5)	36	8 (5.9)	24.5	15 (5.1)	25
general exhaustion	3 (1.9)	2	9 (6.6)	39	12 (4.1)	14
injury	9 (5.8)	24	2 (1.5)	76.5	11 (3.8)	24
tumours	9 (5.8)	98	0 (0.0)	0	9 (3.1)	98
feline leukemia virus (FeLV)	4 (2.6)	117.5	3 (2.2)	54	7 (2.4)	54
feline immunodeficiency virus (FIV)	3 (1.9)	19	1 (0.7)	4	4 (1.4)	15
neurological issues	4 (2.6)	26	0 (0.0)	0	4 (1.4)	26
heart failure	1 (0.6)	44	2 (1.5)	37	3 (1.0)	44
death after surgery	3 (1.9)	180	0 (0.0)	0	3 (1.0)	180
old age	2 (1.3)	200.5	1 (0.7)	1222	3 (1.0)	322
total	156	26	136	28	292	26

* other causes: anaemia, fluid in the abdominal cavity, thrombosis, infanticide, diabetes mellitus, diaphragmatic hernia, poisoning, epilepsy, death due to ingestion of a foreign body.

Table 9

The number and LOS (length of stay) of cats in different age categories depending on the cause of death or euthanasia.

cause of death/euthanasia	age category							
	≤ 6 months		6 < x ≤ 12 months		1 < x ≤ 8 years		> 8 years	
	n (%)	median LOS (days)	n (%)	median LOS (days)	n (%)	median LOS (days)	n (%)	median LOS (days)
feline infectious peritonitis (FIP)	49	99	6	38	8	53	0	0
panleukopenia (FPV)	45	15	3	20	6	17	0	0
upper and lower respiratory tract infections	39	18	6	14,5	5	19	1	10
gastrointestinal problems	13	16	0	0	5	7	1	924
renal failure	1	45	0	0	8	23	8	13,5
fading kitten syndrome	17	12	0	0	0	0	0	0
other causes*	6	25	1	240	5	25	3	24
general exhaustion	9	11	0	0	2	81	1	4
injury	3	24	1	1	6	76,5	0	0
tumours	1	803	0	0	6	30	2	637,5
feline leukemia virus (FeLV)	0	0	0	0	5	61	2	18
feline immunodeficiency virus (FIV)	0	0	0	0	3	19	1	4
neurological issues	3	26	0	0	1	13	0	0
heart failure	1	44	0	0	1	24	1	50
death after surgery	0	0	1	180	2	521	0	0
old age	0	0	0	0	0	0	3	322

* other causes: anaemia, fluid in the abdominal cavity, thrombosis, infanticide, diabetes mellitus, diaphragmatic hernia, poisoning, epilepsy, death due to ingestion of a foreign body.

study - the number of cats that died or were euthanized was relatively low (11.7 %). Even lower mortality rates were found in no-kill facilities in UK by Murray et al. (2008), who reported 4.7 % of cats having died naturally or being euthanized. Although the concept of no-kill shelters is generally more positively accepted by the public in contrast to the view of traditional shelters in which unwanted animals are killed, a problematic aspect may be a prolonged stay in the shelter for animals considered unattractive by adopters. Typically, this is true for older individuals (Kubesova et al., 2017) that may stay in the shelters for months or even years. In our study, the median LOS of cats that died in the shelter due to old age was 322 days. From the point of view of maintaining good quality of life of shelter animals, prolonging the stay in the shelter is a negative aspect, as it contributes to an increased risk of disease. Animals are exposed longer to pathogens possibly present in the environment and to stressful situations in general. Increased mortality may be an indirect consequence of increasing morbidity of individuals.

Although one of the shelters monitored in our study did not distinguish between natural death and euthanasia in their records, the cumulative euthanasia rate in both shelters likely did not exceed 10 %, which is the notional benchmark characterizing shelters with no-kill

policies [Best Friends \(2023\)](#). In Shelter A that recorded natural death and euthanasia separately, only 2 % of cats with untreatable health problems were euthanized. Thus, the majority of animals died naturally. The question, in which cases euthanasia should be preferred is not simple to answer. Several aspects must be taken into account when making a decision, and in shelters, financial, staffing and capacity considerations are particularly important. The shelter must consider whether costly treatment with an uncertain outcome is detrimental to providing adequate care for other animals or whether the treated animal is taking up capacity for individuals that could be admitted and rehomed faster. Providing special care is usually also very time-consuming and can be perceived as stressful from the animal's point of view.

The overall median LOS of cats in the shelters until death or euthanasia was 23 days, the median LOS of animals until death/euthanasia in the shelters A and B differed significantly. Significant differences in median LOS were also found when analysing the individual causes of death/euthanasia. Of the four most frequent causes of death/euthanasia in the cat shelters (FIP, panleukopenia, upper and lower respiratory tract infections, and gastrointestinal problems), the longest median LOS was recorded for cats that died or were euthanized due to FIP. The clinical

signs of FIP vary considerably and the lifespan of diseased cats depends on their progression, which is individual for each cat. Untreated animals have been reported to live for days to weeks in the effusive form and weeks to months in the non-effusive, so-called dry form of FIP Ritz et al. (2007). Although FIP caused death of 24 cats in Shelter A, only 5 of them were euthanized. Currently, FIP is no longer considered an incurable disease, with the first studies suggesting treatment options published in 2018 Murphy et al. (2018); Pedersen et al. (2018). The records collected from Shelter A for the purposes of this study covered a period during which treatment was not yet available. It is therefore questionable what accounts for the low number of animals euthanized due to FIP. One explanation is that a definitive diagnosis was not made until *post mortem*. The diagnosis may be challenging given the variability and non-specificity of possible clinical signs especially when no effusion is present and it requires a series of tests Thayer et al. (2022). The testing procedures are associated with considerable financial costs that may not be available in the shelter.

The overall high percentage of deaths due to FIP is related to the large number of animals infected with feline coronavirus, which is commonly found in facilities with higher concentrations of cats Tasker et al. (2023). Addie et al. (1995) found that coronavirus-specific antibodies were present in up to 90 % of cats in catteries and 50 % of cats in single-cat households. According to (Thayer et al., 2022), the number of cats shedding coronavirus in shelters can be as high as 100 %, and cats can be infected repeatedly. As the virus is transmitted via the oro-faecal route (Tasker et al., 2023), the sharing of toilets by multiple individuals is a risk factor. Testing the virus shedding status in faeces of cats prior to their admission to the shelter and a subsequent separation of virus-shedding animals could prevent spreading the virus. However, testing a sample taken from each animal by PCR would be expensive and the cheaper, commercially available alternative in the form of rapid antigen immunochromatographic tests have not shown sufficient sensitivity Vojtkovská et al. (2022b). An alternative could be immunochromatographic tests detecting antibodies, which have a high level of sensitivity as shown in the study by Addie et al. (2015). The problematic fact is that even animals in which antibodies are not found can actively shed virus Meli et al. (2004).

Although coronavirus-specific antibodies are commonly found in cats, the virus mutates to infectious peritonitis in only about 4–10 % of animals Addie et al. (1995), (2009). The exact mechanism of the mutation has not yet been described, however, several factors are known to be associated with the mutation, one of which is a weakened immune system and stress Thayer et al. (2022). According to (Yin et al., 2021), young cats are more susceptible which is consistent with the results of our study. The highest number of deaths was observed in kittens up to 6 months of age. This age category was the most represented among cats having died or being euthanized in both shelters, which may be attributed to their generally higher susceptibility due to an underdeveloped immune system. Juveniles of all mammalian species are at a greater risk of developing diseases; if the disease develops it usually has a more severe progression than in adult animals Schultz et al. (2010).

Fading kitten syndrome caused death of 5.8 % cats, kittens died within 12 days (median) after being admitted to the shelters monitored for the purposes of this study. Mortality of kittens is the highest within two weeks of life, with more than half of all deaths occurring in this period Fournier et al. (2017). There is usually not a single cause - infectious, traumatic, metabolic and genetic diseases are usually involved Bücheler (1999). As most neonatal diseases manifest similarly, a specific cause cannot be determined only on the basis of clinical signs Münnich (2022). Factors predisposing to mortality include hypothermia, hypoglycaemia, improper husbandry and delayed colostrum intake. Animals admitted to shelters come from different environments - if conditions were not appropriate in the place of origin, death in the shelter is merely a consequence of those conditions. In abandoned kittens found without a mother in wet and cold environments, hypothermia is typically a predisposing factor for mortality Gunn-Moore (2006). General exhaustion

was a cause of death of 9 juveniles, 2 adult cats and one cat over 8 years in our study. Animals that died due to general exhaustion stayed in the shelter less than 14 days. More than half of the cats are admitted to the shelter in poor health according to our earlier study Vojtkovská et al. (2021). Despite the care provided, some animals are unable to survive due to their overall poor condition and stress.

The increased risk of mortality in kittens was also reported by Murray et al. (2008). In their study, 5 times higher risk of mortality was found in the kittens aged up to 7 weeks and in cats older than 7 years. Renal failure, tumours and old age were the causes of death or euthanasia that predominated in adult and older cats over younger animals and kittens in our study. Although renal failure can affect cats of any age, the risk of occurrence raises with increasing age Bartges (2012). Eighty percent of all cats over 15 years are affected Marino et al. (2014). In the case of cancer, a similar phenomenon was reported, with older animals being affected more frequently. (Manuali et al., 2020) who monitored 680 neoplasias diagnosed in 670 cats, found the mean age of animals with benign tumours to be 9.8 ± 3.8 years, and with malignant tumours 9.5 ± 3.3 years.

The second most frequent cause of death or euthanasia in our study was panleukopenia. Similarly, as in the case of FIP, mainly kittens under 6 months of age died or were euthanized due to panleukopenia. This finding is consistent with the results of other studies e.g., Truyen et al. (2009); Barrs et al. (2019); Rehme et al. (2022). The peracute form without apparent premonitory signs is common in kittens, with kittens dying within 12 h due to septic shock, dehydration and hypothermia Greene & Levy (2012). Parvovirus was the cause of death in 25 % of kittens under 4 months of age originated from private homes or shelters within the UK as reported by Cave et al. (2002). According to the authors, kittens in the shelters were significantly more likely to be infected with parvovirus than owned cats. (Rehme et al., 2022) monitored four shelters to determine the risk factors for outbreaks of feline panleukopenia. Panleukopenia occurred in 28 % of cats (42 of 150), shedding of the virus was recorded in 48.7 % of cats. Parvovirus shedding was significantly more common in young cats and group-housed cats. Another important factor for the presence of disease was vaccination - cats that were not vaccinated were up to 47 times more likely to develop infection Rehme et al. (2022). However, active vaccination cannot achieve immediate protection of kittens, so the spread of the disease is not uncommon in shelters. The most likely reason for the susceptibility of kittens is that maternally derived antibodies decline below protective titers but can still neutralize vaccine antigen Jakel et al. (2012). Studies indicate that maternal antibodies can persist up to 16–20 weeks of age DiGangi et al. (2012).

Upper and lower respiratory tract infections were the third most frequent cause of mortality found in our study. Multiple pathogens have been isolated from cats with acute upper respiratory tract disease (URTD) including feline herpesvirus-1 (FHV-1) and feline calicivirus (FCV), other bacterial pathogens of URTD include *Bordetella bronchiseptica*, *Chlamydia felis*, and *Mycoplasma*. Age of an animal (younger individuals are at higher risk (Pedersen et al., 2004; Bannasch & Foley, 2005; Azis et al., 2018)), LOS in the shelter and specific shelter conditions (Bannasch & Foley, 2005) are factors influencing the risk of development of URTD. Although pathogen prevalence varies between shelters, many cats show signs of URTD after only 1 week in the shelter Bannasch & Foley. (2005); Tanaka et al. (2012). According to (Dinnage et al., 2009), up to one-third of all cats in the shelters suffer from URTD. (Azis et al., 2018) reported 25.8 % of animals with URTD after being relocated to the shelter. In the shelter monitored by (Bannasch and Foley, 2005), more than half of cats suffered from URTD. The course of the disease in case of infection with the aforementioned pathogens is usually not fatal, but cases with high mortality rates also have been documented. A generalized form of feline calicivirus has been associated with 30–70 % mortality Schorr-Evans et al. (2003); Foley et al. (2006); Deschamps et al. (2015). In our study, 17.5 % of animals died or were euthanized due to upper and lower respiratory tract infections. A lower

mortality rate (3.7 %) of cats due to respiratory problems was reported by Murray et al. (2008) in the UK adoption centres.

In our study, gastrointestinal problems were the cause of death in 6.5 % of cats. (Murray et al., 2008) reported 9.8 % of shelter cats dying or having been euthanized due to gastrointestinal problems. Other, less frequent causes of mortality in the shelters monitored in our study included death or euthanasia due to injury (3.8 %), FIV (1.4 %), FeLV (2.4 %), neurological problems (1.4 %), heart failure (1 %), and surgery (1 %). In the case of injuries, 7 of 11 deaths involved a collision with a car. A similar number (2.1 %) of shelter cats that succumbed to trauma was reported by Murray et al. (2008). Collision with a car is a common cause of cat mortality in general (McDonald et al., 2017). (Rochlitz, 2004) studied the consequences of car accidents in 128 cats; 21 % of cats died naturally and 5 % of cats were euthanized after a collision. Stray cats were found to have more serious injuries than owned cats. (Marston and Bennett., 2009) monitored the physical and health attributes of cats admitted to the shelters in Australia. Although the authors of this study did not report mortality rates due to injuries, it is interesting to note that up to 10 % of all admitted cats had visible injuries on their bodies, 55 % of which were of an older nature (scratch marks and more extensive injuries probably acquired in fights with other cats) and 28.3 % of which were of a new nature (fresh wounds and injuries acquired as a result of being hit by a car).

The present study has several limitations. Data were obtained from two selected shelters, therefore the findings may not be applicable to all shelters located in the Czech Republic. On the other hand, it is important to note, that in accordance with national legislation, shelter operators are not obliged to keep records regarding health condition and shelter animal outcomes except adoptions by new owners. For that reason, many shelters do not store such data. This fact led us to cooperate with facilities that systematically keep such data. Another limitation is related to the fact that the data provided by the shelters listed for each animal only one cause of death, which was determined by the competent persons in the shelters. Comorbidities that may have been present were not included in the statistical analysis for this reason.

5. Conclusion

According to our findings, overall mortality rates of cats in the monitored shelters were relatively low, the highest mortality risk was found in young animals up to 6 months of age. Therefore, targeted measures (strict compliance with quarantine, vaccination, adaptation of environmental conditions leading to stress reduction, reduction of LOS in the shelter to a minimum and compliance with hygiene procedures) may help to reduce mortality rates in this age category. The infectious diseases (feline infectious peritonitis, panleukopenia and upper and lower respiratory tract infections) were the most commonly found causes of death or euthanasia of cats in both shelters. Shelters that provided data for the purposes of this study keep cats in large groups (more than 15 individuals per group); reduction of the number of cats kept in one group is the general recommendation for reducing infectious pressure in the shelter environment. The application of these measures and their effectiveness should be verified in a future research.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors did not use generative AI and AI-assisted technologies.

CRedit authorship contribution statement

Veronika Vojtkovská: Writing – original draft, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Eva Voslářová:** Writing – review & editing, Supervision, Project administration. **Vladimír Vecerek:** Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Veronika Vojtkovska reports financial support was provided by University of Veterinary Sciences Brno. Veronika Vojtkovska reports a relationship with University of Veterinary Sciences Brno that includes: employment. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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