Original Article

jfms Journal of Feline Medicine and Surgery

Journal of Feline Medicine and Surgery
2021, Vol. 23(8) 730–737

DOI: 10.1177/1098612X20974960
journals.sagepub.com/home/jfm

This paper was handled and processed by the American Editorial Office (AAFP) for publication in *JFMS*

SAGE

Pre-mortem risk factors for mortality in kittens less than 8 weeks old at a dedicated kitten nursery

Emily D Dolan[1], Erin Doyle[2], Huyanh Ralph Tran[3] and Margaret R Slater[1]

Abstract

Objectives Kittens have unique requirements for care in a shelter setting given their higher susceptibility to infectious disease and socialization needs. Significant time and resources are necessary to care for this vulnerable population and dedicated kitten nurseries are one way to meet the requirements of kittens too young for neutering and rehoming. However, young kittens remain at a higher risk of dying relative to adult cats, even in specialized settings. Efforts to investigate kitten mortality have focused on post-mortem findings and little is known about pre-mortem clinical signs that may be associated with death. The purpose of this study was to elucidate predictors of mortality in underage kittens.

Methods The medical records of kittens aged <8 weeks reared in a kitten nursery in New York City during 2017 were examined. The data collected included signalment (estimated age and weight at intake, sex), physical findings (body condition score [BCS]), clinical signs (weight loss, anorexia, diarrhea, upper respiratory tract infection [URI]), diagnoses (panleukopenia, trauma), how early in the feline breeding season the kitten entered (April–November), and whether the kitten had died or was euthanized. The data were analyzed using Cox proportional hazard modeling with 1353 kittens to identify factors associated with any death or euthanasia.

Results Elevated risk of dying was found for kittens in the lightest weight group (13 times greater), diagnosed with panleukopenia (13 times greater), exhibiting weight loss (>9 times greater), diagnosed with URI (almost four times greater), exhibiting anorexia (three times greater), identified with a low BCS at intake (two times greater) and experiencing diarrhea (almost two times greater).

Conclusions and relevance These findings identify clinical signs and diagnoses that can serve as prognostic indicators for underage kitten survival in a shelter/rescue setting and can aid in enhancing protocols for monitoring, intervention and euthanasia decision-making.

Keywords: Kitten nursery; risk factors; mortality; shelter medicine; neonatal care

Accepted: 16 October 2020

Introduction

Each year during the feline breeding season (April–November), most organizations caring for homeless cats experience a significant influx of kittens. This seasonal spike in feline admissions can stretch organizational capacity limits. Per national shelter statistics gathered by the organization Shelter Animals Count, kittens up to 5 months of age represented 42% of the 2017 feline intake for contributing organizations.[1] The high percentage of juvenile feline intake can pose a challenge for shelters.

Kittens have unique requirements for infection control and socialization that are most acute when kittens are below a safe age to be neutered and rehomed, typically

[1]Strategy and Research, American Society for the Prevention of Cruelty to Animals, New York, NY, USA
[2]Shelter Medicine Services, American Society for the Prevention of Cruelty to Animals, New York, NY, USA
[3]Adoptions, Helen Woodward Animal Center, San Diego, CA, USA

Corresponding author:
Emily D Dolan MS, PhD, Strategy and Research, American Society for the Prevention of Cruelty to Animals, 424 East 92nd St, New York, NY 10028, USA
Email: emily.dolan@aspca.org

at or around 8 weeks of age. These underage kittens are highly vulnerable to infectious disease, have critical behavioral socialization needs and require care for an extended period prior to placement. Providing this care in the shelter increases the risk of disease exposure and taxes the shelter's overall capacity. In addition, many shelters are not staffed to provide for the intense around-the-clock husbandry and socialization needs of orphaned kittens.

Shelter programs caring for underage cats dedicate significant time and resources to each kitten. Yet underage kittens are at a higher risk of dying relative to adult cats, with Murray et al[2] finding that, in a shelter setting, kittens <7 weeks of age were four times more likely to die than cats aged 1–3 years.

The existing literature describes kitten mortality rates ranging from 7.9% up to 29.1% for underage kittens in research or breeding colonies.[3–8] Risk factors for kitten mortality identified in these populations include increased litter size,[8] low birth weight[9] and breed,[5] while incompatible blood type between the queen and the tom was not identified as a risk factor.[10]

However, mortality information focused on shelter or rescue kittens is limited. One study showed panleukopenia virus infection as an important cause of kitten death based on post-mortem evaluation of owned and rescue kittens, with a higher prevalence of infection demonstrated in the rescue kittens.[11] Both Ghosh et al[12] and Watson et al[13] identified altered intestinal microbiota in the intestines of terminally ill shelter kittens, including a higher prevalence of *Enterococcus faecalis* (20% in kittens that died vs 4% in healthy kittens)[12] and a higher prevalence of atypical enteropathogenic *Escherichia coli* (18% in kittens that died vs 0% in healthy kittens).[13] Most recently, Strong et al[14] investigated mortality risk factors in shelter kittens with diarrhea and found an 11% mortality rate in the study population with a reduction in risk of mortality related to administration of a vitamin and mineral supplement.

There remains a need for published literature that provides a broad scope of risk factors for mortality in underage shelter kittens. Knowledge of pre-mortem risk factors is helpful to guide discussions about monitoring and prognosis with caretakers. The kitten nursery setting provides an opportunity to evaluate mortality risk factors given the targeted population served and the consistent, detailed monitoring and record keeping for each kitten in the nursery's care. Though the program has since switched to a foster care-based kitten rearing model, during the study year, kittens were cared for at a dedicated on-site kitten nursery program run by a private non-profit animal welfare organization. This study evaluates retrospective data points that represent common signalment factors and clinical signs observed in neonatal kittens, to determine which of these represent significant risk factors for mortality.

Materials and methods

Subjects

A total of 1578 cats were admitted to a kitten nursery program operated by a private, non-profit animal welfare organization in New York City in 2017. The nursery limited intake to queens nursing kittens and underage kittens without a queen. Of these, 1162 were brought in as strays, 401 were transferred from the local open-admission municipal animal shelter, 11 were owner surrendered and four were taken into custody by law enforcement. Only seven of the cats admitted in 2017 were identified as purebred (one Ragdoll, five Siamese and one Snowshoe). All other cats were identified as domestic short-, medium- or longhair. Nursery intake statistics include queens, but data analysis for this study was limited to kittens under 8 weeks of age, admitted during the 2017 season (April–November).

Only kittens that entered the nursery aged <8 weeks were eligible for the study. Kittens left the study as they transitioned out of the nursery for placement, typically at 8 weeks of age. Some kittens remained in the nursery past 8 weeks if they were not yet of weight for spaying or castration (2 lb), required continued care for medical and/or behavioral concerns, or if there were placement capacity limitations.

Care was provided in a separate facility by staff dedicated to caring for this population according to written protocols. Data were routinely recorded during the intake examination and daily medical rounds. Intake examinations were utilized to determine sex and age. Age was estimated based on weight, dentition, other developmental characteristics and comparison with littermates. For record-keeping purposes and owing to software requirements, a specific age in days was determined for each kitten rather than an age range. Clinical signs were observed and noted by all nursery staff, including veterinarians, licensed veterinary technicians and kitten caregivers. Kitten caregivers weighed kittens daily and noted any clinical signs of concern for further evaluation by the medical staff.

Interventions were performed per written medical protocols with individual case management decisions determined by the licensed veterinary technician and/or veterinarian as needed. Infectious disease was managed at the nursery based on capacity considerations and prognosis. Isolation areas were designated for treatment of dermatophytosis, panleukopenia and upper respiratory tract infection (URI). Biosecurity and sanitation protocols were in place to mitigate risks to population health. Kittens with non-contagious illness or injury were housed in the general population while undergoing treatment. Ongoing care and treatment decisions for ill or injured kittens were guided by regular monitoring. Kittens with a poor or grave prognosis (per veterinarian determination) were euthanized.

All kittens were housed in stainless steel single-compartment housing in accordance with recommendations from the Association of Shelter Veterinarians' Guidelines for Standards of Care in Animal Shelters (2011). Kittens remained with littermates whenever possible, to foster their behavioral wellbeing. Socialization with people was facilitated by staff members and trained volunteers in accordance with protocols designed by behavior staff. Socialization was provided to isolated kittens following biosecurity protocols and in consideration of the order of contagion. Kittens were not comingled between litters aside from thoughtful pairing of orphaned singletons per direction from behavior staff and the nursery veterinarians.

Examinations, monitoring and diagnostics were recorded on medical charts. All charts were examined from the 2017 season. Paper charts were retrieved from storage and the key information from the records was entered in Microsoft Excel (Microsoft Office 365 ProPlus) by a team of medical data transcriptionists. Almost 70% of data records entered were checked for accuracy against the original paper record by a second transcriptionist. Five percent of the records were spot checked for accuracy against the original paper record by a veterinarian. Transcriptionists were supervised by the study lead and received training and support from a staff veterinarian who responded to questions and interpreted ambiguous or unclear medical notes.

Data transcribed from the medical charts contained intake characteristics, including: (1) sex and estimated age at intake (in days); (2) weight at intake (in grams); and (3) date of intake and body condition score (BCS; from 1 to 9, based on the Purina Body Condition System).[15] If the BCS was written in the record as a range, it was recorded in our data as the corresponding half point. For example, if the BCS was written as 3–4, it was recorded as 3.5.

Data also included the following clinical signs or diagnoses, and the dates of onset and resolution: (1) panleukopenia (presumptive diagnosis by the nursery veterinarian based on appropriate clinical signs, fecal parvovirus Ag ELISA results and/or additional diagnostics as clinically indicated; yes/no); (2) weight loss (greater than one gram across any time period; yes/no); (3) URI (upper respiratory signs severe enough to warrant treatment; yes/no); (4) anorexia (any instance of appetite score of 0 /1 [see Appendix 1 in the supplementary material] or 0–2 ml of formula); (5) diarrhea (D + or FS 6/7 based on the Purina Fecal Scoring Chart);[16] and (6) the presence of trauma (any trauma, injury or abscess recorded).

Statistical analysis

All analyses were performed using Stata/IC 15.1 (StataCorp). Reported clinical signs and key diagnoses of interest (panleukopenia, weight loss, URI, anorexia, BCS <3.5 at intake, diarrhea and trauma), as well as the kittens' sex, were described using frequencies and percentages. Several categorical covariates of three equal groups were created and described using frequencies for intake date (early in the season: 10 April 2017 to 12 June 2017; middle of the season: 13 June 2017 to 22 August 2017; late in the season: 23 August 2017 to 12 November 2017) and estimated age in days (youngest: 0–20; middle: 21–34; and oldest: 35–56). Four groups were also created for weight in grams (g) by percentiles (65–258 g; 259–393 g; 394–575 g; 576–1202 g) and whether the BCS at intake was under 3.5 (thin or emaciated at intake) or not. All the above variables were included as main effects in the model. Outcome was the time to death, measured as euthanized or died.

In order to account for the diagnosis/signs of panleukopenia, weight loss, URI, anorexia, diarrhea and trauma as potentially time-varying covariates, the data were subjected to episode splitting, where separate episode records were created for each kitten to reflect the beginning and end of an episode of a specific clinical sign. The variables for panleukopenia, weight loss, URI, anorexia, diarrhea and trauma took the value zero up until the time the kittens experienced signs, as marked in their medical chart. At that point, a new episode record was created where that sign variable took the value 'one'. If the sign resolved, the variable returned to the value 'zero'. Time-varying covariates were assumed to be constant within an episode (record).

A Cox proportional hazard model with robust standard errors was fit to identify hazard ratios and predict risk of overall death as the main model. The model presented here considered the changing rate of events over time, as well as the changing number of kittens at risk. Kittens still alive at the end of the study were considered censored. A base model was tested with all covariates as main effects only. Interactions with time were explored and all possible interactions were tested individually for significance. $P < 0.05$ was considered significant. A likelihood ratio test ($P < 0.05$) was used to compare the model without interactions against a model containing interactions. If the likelihood ratio test was found to be significant, this suggested the model with interactions was a better fitting model and the interaction term was included. The link test was used to determine that the model was well specified; that is, all the relevant variables had been included and no additional variables would be statistically significant beyond chance. The proportional hazards assumption was checked using *stphtest* and was considered met if the global test was not significant. Robust standard errors were calculated to account for kittens having multiple records in the hazard analysis.

Results

In total, 1578 cats were admitted into the nursery in 2017. After excluding queens and kittens aged ⩾8 weeks of age at admission (98 records), as well as those cats that did not have medical records available (117 records, 16 of which had died) for analysis, the resulting data set contained 1363 kittens. Ten kittens were dropped for extreme values of length of stay that lay outside 1.5 times the interquartile range. Thus, a total of 1353 kitten records were included in the analysis. The frequencies of reported clinical signs and intake characteristics in all study kittens are described in Table 1.

The median estimated age was 29 days (range 0–56 days) and the median weight was 395.5 g (range 65–1202 g) at the time of intake. Kittens had a median length of stay in the nursery of 43 days (range 0–110 days).

Table 1 Reported clinical signs, diagnoses and intake characteristics for 1353 kittens from a New York City kitten nursery in 2017

	Did not die (n = 1183)	Died (n = 170)	Total (n = 1353)
Clinical signs/diagnoses			
Panleukopenia			
No	1174 (99)	166 (98)	1340 (99)
Yes	9 (1)	4 (2)	13 (1)
Weight loss			
No	225 (19)	61 (36)	286 (21)
Yes	958 (81)	109 (64)	1067 (79)
URI			
No	696 (59)	139 (82)	835 (62)
Yes	487 (41)	31 (18)	518 (38)
Anorexia			
No	545 (46)	102 (60)	647 (48)
Yes	638 (54)	68 (40)	706 (52)
BCS <3.5 upon intake			
No	896 (76)	89 (52)	985 (73)
Yes	191 (16)	52 (31)	243 (18)
Missing	96 (8)	29 (17)	125 (9)
Diarrhea			
No	291 (25)	87 (51)	378 (28)
Yes	892 (75)	83 (49)	975 (72)
Trauma			
No	1030 (87)	155 (91)	1185 (88)
Yes	153 (13)	15 (9)	168 (12)
Intake characteristics			
Weight at intake, categorized (g)			
65–258	215 (18)	119 (70)	334 (25)
259–393	308 (26)	27 (16)	335 (25)
394–575	332 (28)	9 (5)	341(25)
576–1202	326 (28)	12 (7)	338 (25)
Missing	2 (0.2)	3 (2)	5 (0.4)
Time in feline breeding season intake occurred			
Early (10 April to 12 June 2017)	378 (32)	67 (39)	445 (33)
Middle (13 June to 22 August 2017)	390 (33)	61 (36)	451 (33)
Late (23 August to 12 November 2017)	415 (35)	42 (25)	457 (34)
Sex			
Female	572 (48)	72 (42)	644 (48)
Male	611 (52)	97 (57)	708 (52)
Missing	0 (0.0)	1 (0.6)	1 (0.1)
Age, categorized			
Youngest	258 (22)	118 (69)	376 (28)
Middle	394 (33)	29 (17)	423 (31)
Oldest	531 (45)	23 (14)	554 (41)

Data are n (%)
URI = upper respiratory tract infection; BCS = body condition score

Results from the multivariable model are shown in Table 2. The global test revealed the proportional hazards assumption was met. There were two interactions that improved the model fit: weight loss by intake weight and URI by time in the kitten season. An example of the interpretation of the adjusted hazard ratio is as follows: after adjusting for all other variables, the risk of dying with panleukopenia was very high – 13 times greater than a kitten without panleukopenia. When a kitten had experienced a trauma, however, the risk of dying decreased by approximately 60% (1–0.4) after accounting for all other variables.

The adjusted hazard rates in Table 2 show that kittens with weight loss had a higher risk of dying than kittens without weight loss. Similarly, kittens that entered the nursery in the lower and mid-weight ranges had a greater risk of death than kittens in the higher weight range. Coupling these factors, while not significant, it is noteworthy that kittens which were in the lowest weight range at intake and which also lost weight while

Table 2 Multiple Cox proportional hazard model of kittens' risk of dying for 1353 kittens from a New York City kitten nursery in 2017

Variable	aHR (95% CI)	*P* value
Clinical signs/diagnoses		
Panleukopenia	13 (1.2–133)	0.03
Weight loss	9.3 (2.7–32)	<0.001
URI	3.8 (1.3–11)	0.01
Anorexia	3.3 (2.0–5.4)	<0.001
BCS <3.5 at intake	1.9 (1.2–2.9)	<0.01
Diarrhea	1.5 (1.0–2.1)	0.05
Trauma	0.4 (0.2–0.7)	<0.01
Intake characteristics		
Weight at intake, categorized (g)		
65–258	13 (3.1–58)	0.001
259–393	3.0 (0.7–13)	0.1
394–575	1.4 (0.4–5.7)	0.6
576–1202	Reference	
Time in season intake occurred		
Early (10 April to 12 June 2017)	0.1 (0.01–0.2)	<0.001
Middle (13 June to 22 August 2017)	0.3 (0.1–0.8)	0.02
Late (13 August to 12 November 2017)	Reference	
Female	0.9 (0.6–1.3)	0.6
Age, categorized		
Youngest	Reference	
Middle	0.6 (0.3–1.1)	0.1
Oldest	0.7 (0.3–2.0)	0.5
Interactions		
Weight loss by intake weight interaction		0.02
Weight loss in 65–258 g group	34 (–20 to 88)	0.2
No weight loss in 65–258 g group	13 (–6.2 to 33)	0.2
Weight loss in 259–393 g group	4.8 (–3.4 to 13)	0.3
No weight loss in 259–393 g group	3.0 (–1.3 to 7.3)	0.2
Weight loss in 394–575 g group	4.7 (–2.9 to 12)	0.2
No weight loss in 394–575 g group	1.4 (–0.6 to 2.4)	0.2
Weight loss in 576–1202 g group	9.3 (–2.1 to 21)	0.1
No weight loss in 576–1202 g group	Reference	
URI by time in season intake occurred interaction		0.02
URI intake early in season (10 April to 12 June 2017)	0.03 (–0.02 to 0.1)	0.3
No URI intake early in season (10 April to 12 June 2017)	0.1 (–0.01 to 0.1)	0.1
URI intake in middle of season (13 June to 22 August 2017)	0.7 (–0.1 to 1.5)	0.1
No URI intake in middle of season (13 June to 22 August 2017)	0.3 (0.03–0.6)	0.03
URI intake late in season (13 August to 12 November 2017)	3.8 (–0.3 to 7.9)	0.1
No URI intake late in season (13 August to 12 November 2017)	Reference	

aHR = adjusted hazard ratio; CI = confidence interval; URI = upper respiratory tract infection; BCS = body condition score in the nursery were at substantially higher risk of dying (34 times) than those not losing weight and being in the heavier weight ranges.

The adjusted hazard rates in Table 2 for the interaction of URI with the time in the season that a kitten entered the nursery show that kittens that came in earlier in the season and also showed clinical signs of URI had a lower risk of death than kittens that came in later in the season and showed signs of URI.

Discussion

The results of this study reveal that there are intake characteristics, clinical signs and diagnoses that can be utilized to identify the most vulnerable underage kittens in a nursery or shelter setting. Low weight at intake, panleukopenia infection, weight loss, upper respiratory signs, anorexia, low BCS at intake and diarrhea were all identified as significant risk factors for mortality in this study. The identification of these risk factors can help clinicians to assess relative risk of mortality for underage kittens, which, in turn, can guide intervention decisions.

The highest mortality risk factor identified in this population was weight at intake, with the lightest kittens having a risk of death 13 times greater than those kittens in the heaviest weight group. As would be expected given the relationship between age and weight,[17] most kittens in the 65–258 g (lightest) group were, indeed, also in the youngest age group. A proportion of the kittens in the 65–258 g (lightest) group, however, was in an older age percentile, indicating that they were underweight for their age, though this could be normal variation. Breed could be a potential cause of normal size variation. However, the low prevalence of purebred cats in this population made breed unlikely to be a major factor in these findings. Interestingly, the majority of underweight kittens did not have a BCS <3.5, supporting potential for normal variation in this population. However, a low birth weight, poor weight gain and/or weight loss may all result in a kitten being underweight and might all correlate with malnutrition or disease.[7] We did not capture data on colostrum ingestion in study kittens, though lack of adequate colostrum ingestion may also have contributed to the higher mortality risk in these young and underweight kittens.[18]

As expected, weight loss was also a significant risk factor for mortality, with kittens displaying weight loss being about nine times more likely to die than those kittens without weight loss. Not surprisingly, kittens that were smaller at intake and that also displayed weight loss were more likely to die than either kittens with weight loss that were larger at intake or smaller kittens that did not experience weight loss. This finding is clinically intuitive as weight loss is a common indicator of illness or malnutrition, and the smallest kittens would be expected to be the most susceptible to these concerns. This also highlights the critical need to closely monitor the weight of kittens, especially those that are in the lightest weight group, even when their BCS is adequate.

URI was also significantly associated with mortality, with kittens nearly four times more likely to die when they were clinically affected with URI. While URI is not generally considered fatal, underage kittens are at greater risk for more significant sequelae to infection.[19,20] In our population, there was a small but significant interaction between the URI mortality risk and the time of year of admission into the nursery ($P = 0.02$), with kittens admitted in the middle of the season that developed URI less likely to die than kittens with URI admitted late in the season. The nursery is an inherently limited admission program with capacity limitations dictated by housing and staffing, but in the first few weeks of the season it often operates well below capacity, potentially allowing for enhanced monitoring and intervention capabilities. Later in the season, as the nursery population reaches capacity, there may also be the potential for pathogen transmission, despite protocols and procedures to mitigate this risk. Seasonal variations in the prevalence of different URI pathogens would also have the potential to impact URI-associated mortality. The seasonal variation in this study could also be unique to the 2017 season or the New York City location. Further research to explore URI mortality risk factors in a foster care-based kitten rearing model, as well as seasonal URI pathogen variation, could provide additional valuable information regarding URI and kitten mortality risk.

Kittens with anorexia or a low BCS at intake were approximately 2–3 times more likely to die than kittens with normal appetites or adequate body conditions, respectively. Both findings are clinically intuitive given the association between anorexia and poor body condition with illness. Whether one leads to the other, or whether there is an underlying disease or nutritional component could not be determined from this study. Our findings indicate, however, that both are risk factors that signal a need for prompt intervention when identified in kittens.

Kittens with diarrhea had a risk of dying that was 45% higher than kittens without diarrhea. Seventy-two percent of the kittens in this study were diagnosed with diarrhea at some point during their nursery stay, making it the second most commonly noted clinical sign after weight loss. This incidence is higher than that noted elsewhere in the literature,[14] which may be reflective of the close monitoring of kittens in the nursery. Diarrhea may also be more common in a nursery setting than in other environments such as foster care, owing to the interplay between crowding, disease exposure, stress and nutrition in underage kittens. While diarrhea alone resulted in a modest increase in mortality risk, panleukopenia infection as diagnosed by the veterinarian was associated with nearly 13 times the risk of dying. This is expected given the serious nature of panleukopenia infection and is consistent with other findings demonstrating panleukopenia as a common cause of death in kittens,[11] though it is worth noting that the majority of kittens diagnosed with panleukopenia infection did not die.

The precise timing of the clinical signs was estimated as closely as possible based on daily records; however, if clinical signs occurred within a close time frame to each other (within about 24 h) the data did not indicate which sign or diagnosis came first. The current results show that diarrhea and anorexia, as well as weight loss and panleukopenia, were all independent predictors of mortality; this implies that these clinical signs and diagnoses are important separately and the results are likely not due to a cascade of signs being caused by each other (eg, anorexia or diarrhea leading to weight loss).

The episode-splitting technique utilized for data analysis in this population provided the ability to assess mortality risk at the time of death for the clinical sign of concern. This technique allowed for the de-emphasis of the clinical signs that did not coincide with the time of mortality for specific kittens. More closely evaluating the timing of signs relative to the time of the outcome maximizes the clinical applicability of these risk factors of mortality.

Not all variables analyzed resulted in an increased risk of mortality. Sex had no significant impact on mortality risk. Trauma also did not increase the risk of mortality in our population and in fact had a protective effect. Trauma is a broad category that reflects both very minor concerns such as a collar caught in the mouth ranging to more serious concerns such as an abscess or musculoskeletal trauma. As such, it is difficult to draw definitive conclusions regarding the reason behind the protective effect noted in this population. It is possible that these kittens received intervention and close monitoring that prevented other more significant disease and/or that minor trauma may have been overlooked by the clinician if more serious disease concerns were present. While the protective impact of trauma cannot be fully elucidated, these findings at least suggest that kittens diagnosed with mild-to-moderate trauma generally do not need to be considered at higher risk of mortality.

Limited information exists with which to compare this study population. The overall mortality rate in this study (13%) is comparable with published mortality rates of underage kittens. No apparent intake demographics in this study population differ importantly from the demographics of other underage shelter kitten populations, though potential geographic variation in infectious disease prevalence is important to consider. The transfer of many kittens from a local partner organization would exclude from our study population severely ill or injured kittens that were euthanized or died prior to transfer; however, in the study year few kittens were excluded from transfer. It is uncertain how mortality risk factors for the nursery model compare with foster-based programs or other shelter kitten-management models; however, some degree of commonality can be anticipated given the similar conditions kittens were exposed to prior to shelter intake.

While these results provide robust information to evaluate kitten mortality risk factors for shelter kittens, several limitations of the study are important to consider. The identified risk factors describe associations but do not necessarily identify the cause of death for at-risk kittens. Many variables overlap with one another in typical clinical presentations. Although the model did not show a significant interaction between many putatively related issues, it is still possible that kittens with multiple issues are at higher risk of death.

Another limitation is that data transcription from paper records was utilized to capture the information analyzed in this study. While a vigorous quality assurance process that included multiple quality checks was instituted, there is still the possibility that the data may contain recording mistakes. Further, because of the paper record procedures at the nursery and the retrospective nature of this study (clinicians were unaware at the time of recording that their notes would be used for data and were not following a formal study protocol) clinicians may not have recorded events as completely or reliably on each and every record. In addition, while there was some information on whether kittens had littermates and/or queens, it was not possible to reliably match the litters/queens or to determine if littermates had signs or had died.

Finally, this study was focused on the kittens cared for by one program during a single season in a large metropolitan area and caution should be exercised in extrapolating these results to all programs, populations or areas where kittens are cared for. It is difficult to determine how relevant these findings may be for kittens primarily reared in a foster home vs a nursery setting, for example, as foster care would be expected to mitigate certain concerns such as disease transmission, socialization and caregiver capacity limitations. More research on clinical signs and timing are needed to help support and guide foster-based programs about risk of kitten mortality. However, because this study population represents a typical underage kitten population entering an animal welfare organization there is reason to support generalizability of these findings to provide important information about risk factors for mortality in shelter kittens.

Conclusions

While these results alone cannot dictate clinical decision-making, they provide another tool for the clinician to determine prognosis and guide care decisions for underage kittens in the shelter setting. The kittens in the lowest weight category at intake were at highest risk of mortality, followed by kittens diagnosed with panleukopenia virus and then those displaying weight loss. URI, anorexia or a thin body condition resulted in moderate increases in the mortality risk, while diarrhea brought about a smaller increase in the risk of dying. This information provides a window into which kittens are at greatest risk of mortality in a nursery population. Mortality risk factors can be used to aid kitten nursery programs in fine-tuning protocols to quickly identify and more closely intervene for kittens that may die, and to help guide euthanasia decisions.

Acknowledgements The authors wish to thank the team of medical data transcriptionists for collecting the data for this study. We wish to thank Sharon Pailler, Vic Spain and H Morgan Scott for technical assistance and advice on the statistical methods. We wish to thank Holly Memoli and Stephanie Janeczko for their thoughts on the design and execution of the study. We also wish to thank Hugh Mulligan for data assistance.

Supplementary material The following file is available online:
Appendix 1: Kitten nursery appetite score.

Author note Early findings were presented at the American Board of Veterinary Practitioners Symposium, 2019.

Conflict of interest The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding The authors received no financial support for the research, authorship, and/or publication of this article.

Ethical approval This work involved the use of non-experimental animals only (including owned or unowned animals and data from prospective or retrospective studies). Established internationally recognized high standards ('best practice') of individual veterinary clinical patient care were followed. Ethical approval was therefore not specifically required for publication in *JFMS*.

Informed consent Informed consent (either verbal or written) was obtained from the owner or legal custodian of all animal(s) described in this work (either experimental or non-experimental animals) for the procedure(s) undertaken (either prospective or retrospective studies). No animals or humans are identifiable within this publication, and therefore additional informed consent for publication was not required.

ORCID iD Emily D Dolan https://orcid.org/0000-0003-3319-8933

References

1 Shelter Animals Count. **National database.** https://shelsteranimalscount.org/ (2017, accessed 22 November 2019).
2 Murray JK, Skillings E and Gruffydd-Jones TJ. **A study of risk factors for cat mortality in adoption centres of a UK cat charity.** *J Feline Med Surg* 2008; 10: 338–345.
3 Sparkes AH, Rogers K, Henley WE, et al. **A questionnaire-based study of gestation, parturition and neonatal mortality in pedigree breeding cats in the UK.** *J Feline Med Surg* 2006; 8: 145–157.
4 Young C. **Preweaning mortality in specific pathogen free kittens.** *J Small Anim Pract* 1973; 14: 391–398.
5 Ström Holst B and Frössling J. **The Swedish breeding cat: population description, infectious diseases and reproductive performance evaluated by a questionnaire.** *J Feline Med Surg* 2009; 11: 793–802.
6 Fournier A, Masson M, Corbière F, et al. **Epidemiological analysis of reproductive performances and kitten mortality rates in 5,303 purebred queens of 45 different breeds and 28,065 kittens in France.** *Reprod Domest Anim* 2017; 52: 153–157.
7 Root Kustritz MV. History and physical examination of the neonate. St Louis, MO: Elsevier, 2011.
8 Romagnoli S, Bensaia C and Ferre-Dolcet L. **Fertility parameters and reproductive management of Norwegian Forest Cats, Maine Coon, Persian and Bengal cats raised in Italy: a questionnaire-based study.** *J Feline Med Surg* 2019; 21: 1188–1197.
9 Lawler DF and Monti KL. **Morbidity and mortalitiy in neonatal kittens.** *Am J Vet Res* 1984; 45: 1455–1459.
10 Axnér E. **A questionnaire on survival of kittens depending on the blood groups of the parents.** *J Feline Med Surg* 2014; 16: 781–787.
11 Cave TA, Thompson H, Reid SWJ, et al. **Kitten mortality in the United Kingdom: a retrospective analysis of 274 histopathological examinations (1986 to 2000).** *Vet Rec* 2002; 151: 497–501.
12 Ghosh A, Borst L, Stauffer SH, et al. **Mortality in kittens is associated with a shift in ileum mucosa-associated enterococci from *Enterococcus hirae* to biofilm-forming enterococcus faecalis and adherent *Escherichia coli*.** *J Clin Microbiol* 2013; 51: 3567–3578.
13 Watson VE, Jacob ME, Flowers JR, et al. **Association of atypical enteropathogenic Escherichia coli with diarrhea and related mortality in kittens.** *J Clin Microbiol* 2017; 55: 2719–2735.
14 Strong SJ, Gookin JL, Correa MT, et al. **Interventions and observations associated with survival of orphaned shelter kittens undergoing treatment for diarrhea.** *J Feline Med Surg* 2020; 22: 292–298.
15 Nestle Purina PetCare Center. **Nestle Purina body condition system.** https://www.aspcapro.org/sites/default/files/nestle_body_condition_scale.pdf (accessed 22 November 2019).
16 Purina. **Fecal scoring chart.** https://www.proplanveterinarydiets.ca/wp-content/uploads/2016/04/PPPVD-Fecal-Scoring-Chart-EN-FINAL.pdf (accessed 22 November 2019).
17 DiGangi BA, Graves J, Budke CM, et al. **Assessment of body weight for age determination in kittens.** *J Feline Med Surg* 2020; 22: 322–328.
18 Chastant-Maillard S, Aggouni C, Albaret A, et al. **Canine and feline colostrum.** *Reprod Domest Anim* 2017; 52: 148–152.
19 Sykes JE. **Pediatric feline upper respiratory disease.** *Vet Clin North Am Small Anim Pract* 2014; 44: 331–342.
20 Ruaux C. **The respiratory system.** In: Peterson ME and Kutzler MA (eds). Small animal pediatrics. St Louis, MO: Elsevier, 2011, pp 328–339.