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Morbidity and mortality of domestic rabbits (*Oryctolagus cuniculus*) under primary veterinary care in England

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Abstract

Background The domestic rabbit is a common pet species, but limited research exists on the health of pet rabbits. This study aimed to characterise common disorders of pet rabbits and reasons for mortality as recorded by veterinary practices in England.

Methods This cross-sectional study covered anonymised clinical records of 6349 rabbits attending 107 primary veterinary care clinics.

Results The median age was 3.2 years (interquartile range (IQR) 1.6–5.1), and the median adult bodyweight was 2.1 kg (IQR 1.7–2.6). The most common breed types were domestic (n=2022, 31.9 per cent), lop (1675, 26.4 per cent) and Netherland dwarf (672, 10.6 per cent). For those rabbits that died during the study period, the median age at death was 4.3 years (IQR 2.1–7.0). The most common causes of death were recorded as myiasis (prevalence 10.9 per cent, 95 per cent confidence interval (CI): 7.4 to 15.2), anorexia (4.9 per cent, 95 per cent CI: 4.0 to 10.4), recumbency/collapse (4.9 per cent, 95 per cent CI: 4.0 to 10.4) and ileus (4.3 per cent, 95 per cent CI: 3.5 to 9.5). The most prevalent specific disorders recorded were overgrown claw/nails (16.0 per cent, 95 per cent CI: 14.5 to 17.5), overgrown molar(s) (7.6 per cent, 95 per cent CI: 6.6 to 8.7), perineal soiling (4.5 per cent, 95 per cent CI: 3.7 to 5.4), overgrown incisor(s) (4.3 per cent, 95 per cent CI: 3.5 to 5.2) and ileus (4.2 per cent, 95 per cent CI: 3.4 to 5.0).

Conclusions This study augments the limited evidence base on rabbit health and can assist veterinarians to better advise owners on optimal animal husbandry priorities.

Introduction

The domestic rabbit (*Oryctolagus cuniculus*) is a common pet species, with an estimated one million pet rabbits in the UK.[1 2] Exhibiting rabbits has been a popular hobby for 200 years, with over 50 breeds and over 500 varieties currently recognised by the British Rabbit Council.[3] Captive breeding and a desire for phenotypic variation encourages substantial changes to the modern rabbit's size, conformation and fur type, with consequent breed-specific disease predispositions suspected but with limited confirmatory evidence.[4–8] Despite their conformational variation, the pet rabbit appears to retain a range of expressed behaviours similar to the European wild rabbit, suggesting that domestication has not significantly changed their behavioural needs.[9]

Traditionally regarded as a children's pet, until recently rabbits were commonly housed outdoors in a hutch and fed a mainly concentrate-based diet.[10] More recent studies report changing ownership profiles, with increasing ownership primarily by adults.[11] Rabbits are now frequently kept indoors, and there appears to be increased awareness by owners that rabbits need hay as a key dietary constituent.[2] However, studies continue to reveal serious welfare issues affecting large proportions of pet rabbits, including inappropriate housing, lack of companionship and improper diet.[11] A survey of owners at point of purchase identified their limited knowledge of the basic needs of rabbits.[12] Regular veterinary visits have, however, been associated with increased knowledge by owners about rabbit care and therefore constitute an important opportunity for further owner education, in addition to identifying and managing underlying disease.[13]

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A survey of 167 apparently healthy pet rabbits in Finland reported a high prevalence of both clinical and radiological abnormalities on full clinical examination, highlighting the rabbit's ability as a prey animal to disguise external signs of disease.[14] Acquired dental disease was the most common disorder, followed by vertebral column deformities and degenerative lesions, skin disorders and eye disorders. Unfortunately, there is a paucity of reliable and generalisable data regarding the prevalence of common disorders within the UK pet rabbit general population. A survey of 102 rabbits in the UK reported dental disease as the most common disorder, followed by respiratory and ocular diseases.[15] Another survey of 97 rabbits in the UK reported the most common presenting problems as ocular discharge, overgrown incisors and obesity.[16] There does, however, appear to be a mismatch between the common conditions reported in rabbits and the priority given to these conditions in the published information.[17] Further information on the common conditions affecting pet rabbits would help highlight current knowledge gaps and assist to develop targeted improvements in education of clinicians and owners, as well as to prioritise research.

Primary-care veterinary clinical data have been recognised as a valuable data resource for health analyses of large counts of animals that are representative of the wider pet population.[18–20] It is important to note, however, that in primary-care practice, veterinarians and owners may be more focused on resolution of the presenting problem rather than reaching a specific diagnosis and that this distinction may be even more apparent for rabbits than for cats or dogs.[21] It is additionally possible that some conditions may be misdiagnosed or missed completely due to reduced familiarity of owners and veterinarians with normal and abnormal physiology and behaviour.[13] Veterinary clinical records for rabbits should therefore be considered as a good source of data on their presenting problems and presumed diagnoses, rather than as a resource that defines precise biomedical disease terms.

Using veterinary clinical data from the VetCompass programme,[22] this study aimed to characterise the commonly diagnosed disorders of pet rabbits and the reasons for mortality as recorded by veterinarians in primary-care practice in England. The results from the current study could provide a valuable framework to improve welfare in rabbits by providing an evidence base for disorder prioritisation based on prevalence.

Materials and methods

The study population included all rabbits under primary veterinary care at clinics in England participating in the VetCompass programme during 2013. Rabbits under veterinary care were defined as those with either (1) at least one electronic patient record (EPR) (free-text clinical note, treatment or bodyweight) recorded during 2013 or (2) at least one EPR recorded both before and after 2013. The VetCompass programme collates anonymised EPR data from primary-care veterinary practices in the UK for epidemiological research.[22] Data fields available to VetCompass researchers for each rabbit included a unique animal identifier along with species, breed, date of birth, sex, neuter status and bodyweight. Clinical information from free-form text clinical notes and treatments with relevant dates were also available. A cross-sectional study design was used to estimate the one-year period prevalence of the most commonly recorded diagnoses in 2013.[23] Prevalence was estimated using a random sample of rabbits taken from the overall study population; time constraints precluded extracting disorder data on all available rabbits. An a priori sample size calculation estimated that a minimum of 2356 rabbits would need to be sampled to represent a disorder with at least 2.5 per cent expected prevalence to a precision of 0.5 per cent with 95 per cent confidence level from a study population of 6349 rabbits.[24]

The list of unique animal identification numbers for all rabbits was randomly ordered, and the clinical records of a randomly selected subset of animals were reviewed manually in detail to extract the most definitive diagnoses recorded for all disorders during 2013.[20] No distinction was made between pre-existing and incident presentation. Individual disorders described within the clinical notes using one or more presenting sign terms but without a formally recorded diagnostic term were included using the first sign listed (eg, 'anorexia and lethargy' was included as 'anorexia'). Mortality data (cause of death, date and method of death) were extracted on all deaths at any date from the available EPR data. Elective (eg, neutering) or prophylactic (eg, vaccination) clinical events were not included in the current analyses.

The extracted diagnosis terms were mapped to a dual hierarchy of diagnostic precision for analysis: specific precision and grouped precision as previously described.[20] Briefly, fine precision terms described the original extracted terms at the highest level of diagnostic precision provided by the information recorded in the clinical notes (eg, *Abscess - limb* would remain as *Abscess - limb*). Grouped precision terms mapped the original diagnosis terms to a general level of diagnostic precision (eg, *Abscess - limb* would map to *Abscess*).

Following data checking and cleaning in Excel (Microsoft Office Excel V.2013, Microsoft), analyses were conducted using Stata V.13 (Stata). The breed data recorded by the originating practices were mapped to a list of rabbit breed terms that was iteratively derived from the source data. *Adult bodyweight* (kg) described the mean bodyweight recorded from all bodyweight data available for each rabbit aged over six months. *Neuter* described the status of the rabbit (entire or neutered) at the final EPR. *Age* (years) described the age at the final

date under veterinary care during 2013 (December 31, 2013).

Descriptive statistics reported the sex, neuter, age and adult bodyweight for all rabbits under veterinary care during 2013. From the random subset of rabbits with disorder data extracted, one-year (2013) period prevalence values were estimated along with 95 per cent confidence intervals (CIs) that described the probability of diagnosis at least once during 2013. The CI estimates were derived from standard errors based on approximation to the binomial distribution for disorders with at least 10 events[25] or the Wilson approximation method for disorders with fewer than 10 events.[26] Prevalence values were reported overall and also separately for males and females. The chi-squared test (or Fisher's exact test when at least one expected value was less than 5) was used to compare proportional neutering and disorder prevalence between the sexes.[25] The Mann-Whitney U test was used to compare age and bodyweight differences between the sexes.[25] Statistical significance was set at 5 per cent.

Results

Demography

The study population comprised 6349 rabbits under veterinary care during 2013 from 107 clinics in the VetCompass database. Data completeness varied across the variables assessed: age 98.8 per cent, sex 98.5 per cent, breed 97.8 per cent, neuter status 19.7 per cent and adult bodyweight 5.4 per cent. Of the rabbits with information available, the median age overall was 3.2 years (interquartile range (IQR) 1.6–5.1, range 0.1–14.3). The median age of males (3.3 years, IQR 1.6–5.3, range 0.1–14.3) was higher than for females (3.1 years, IQR 1.5–4.9, range 0.1–13.9) (P=0.007). There were 3429 (54.7 per cent) male rabbits and 2830 (45.3 per cent) female rabbits. Overall, 906 (72.42 per cent) of the rabbits with neuter status available were neutered. There was an observed difference in neuter probability between males and females (72.5 per cent v 73.2 per cent, respectively), but this was not considered to be statistically significant (P=0.766). The median adult bodyweight overall was 2.1 kg (IQR 1.7–2.6, range 0.7–6.3). There was an observed difference between the median adult bodyweight of males (2.2 kg, IQR 1.7–2.6, range 0.8–6.3) and females (2.1 kg, IQR 1.7–2.7, range 0.7–5.9), but this was not considered to be statistically significant (P=0.979). The most common breed types were recorded as domestic (n=2022, 31.9 per cent), lop (1675, 26.4 per cent) and Netherland dwarf (672, 10.6 per cent) (table 1).

Table 1 Common breed types of rabbit under primary veterinary care at practices participating in the VetCompass programme in England from January 1, 2013 to December 31, 2013 (n=6349)

Breed	Count	%	Median adult (>6 months) bodyweight (kg)
Domestic	2022	31.9	2.3
Lop	1675	26.4	2.4
Netherland dwarf	672	10.6	1.4
Crossbreed specified	393	6.2	2.1
Lionhead	361	5.7	2.1
Miniature lop	216	3.4	1.8
Dutch	175	2.8	2.1
Dwarf lop (mini lop)	162	2.6	1.9
Rex	126	2.0	2.4
Others	547	8.7	2.2

Mortality

The median age at death of the 370 rabbits that died during the study was 4.3 years (IQR 2.1–7.0, range 0.1–14.4). For males, the median age at death was older (5.2 years, IQR 3.0–8.1, range 0.2–14.4) than for females (3.7 years, IQR 2.0–5.9, range 0.1–11.8) (P<0.001). There were 103 (27.8 per cent) rabbits that died without a recorded cause of death in their clinical notes. Of the remaining 267 deaths, the most common causes of death recorded were myiasis (flystrike) (n=29, prevalence 10.9 per cent, 95 per cent CI: 7.4 to 15.2), anorexia (n=18, 4.9 per cent, 95 per cent CI: 4.0 to 10.4), recumbency/collapse (n=18, 4.9 per cent, 95 per cent CI: 4.0 to 10.4) and ileus (n=16, 4.3 per cent, 95 per cent CI: 3.5 to 9.5). Among the eight most common causes of death recorded, the median age at death varied from 1.7 years for myxomatosis up to 6.4 years for anorexia (table 2).

Disorder prevalence

The EPRs of the study sample of 2506 rabbits (39.5 per cent of study population) were manually examined to extract diagnosis data for all disorders recorded during 2013. There were 1433 rabbits (57.2 per cent) with at least one disorder recorded during 2013, while the remaining 42.8 per cent had no disorder recorded and either presented for prophylactic management only or did not present at all during 2013. The median annual disorder count per rabbit during 2013 was 1 disorder (IQR 0–1, range 0–12) and did not vary between males and females (P=0.592).

There were 2553 unique disorder events recorded during 2013 from the study sample of 2506 rabbits that encompassed 192 distinct fine precision terms. The most prevalent fine precision disorders recorded were overgrown claw/nails (n=400, prevalence 16.0 per cent, 95 per cent CI: 14.5 to 17.5), overgrown molar(s) (n=190, 7.6 per cent, 95 per cent CI: 6.6 to 8.7), perineal soiling (n=113, 4.5 per cent, 95 per cent CI: 3.7 to 5.4), overgrown incisor(s) (n=108, 4.3 per cent, 95 per cent CI: 3.5 to 5.2) and ileus (n=104, 4.2 per cent, 95 per cent CI: 3.4 to 5.0). Males had statistically significant higher prevalence than females for four of the 24 most common fine precision disorders (overgrown claw/nails, overgrown molar(s), overgrown incisor(s) and dental disease). The median age of rabbits affected with

Table 2 Causes of mortality in rabbits recorded at primary veterinary care practices participating in the VetCompass programme in England from January 1, 2013 to December 31, 2013 (n=370)

Cause of death	Count	% of all deaths	% of deaths with cause recorded	Median age at death (years)
Death—unrecorded cause	103	27.8	–	4.4
Myiasis (flystrike)	29	7.8	10.9	5.4
Anorexia	18	4.9	6.7	6.4
Recumbency/collapse	18	4.9	6.7	5.0
Ileus	16	4.3	6.0	3.7
Head tilt	14	3.8	5.2	4.2
Myxomatosis	14	3.8	5.2	1.7
Bite injury	13	3.5	4.9	2.0
Encephalitozoon cuniculi infection	10	2.7	3.7	3.0
Other	135	36.5	50.6	

common disorders varied from 1.6 years for bite injury up to 5.4 years for myiasis (table 3).

Fine precision disorders were categorised into 24 distinct grouped precision disorder terms. The most prevalent grouped disorders were dermatological (n=505, prevalence 20.2 per cent, 95 per cent CI: 18.6 to 21.8), oral (n=272, prevalence 10.9 per cent, 95 per cent CI: 9.7 to 12.1), gastrointestinal/abdominal (n=238, prevalence 9.5 per cent, 95 per cent CI: 8.4 to 10.7), ocular (n=182, prevalence 7.3 per cent, 95 per cent CI: 6.3 to 8.3) and parasitic (n=178, prevalence 7.1 per cent, 95 per cent CI: 6.1 to 8.2). Males had a higher prevalence than females for two disorder groups: oral and auditory (table 4).

Discussion

This study of over 2000 animals is the largest analysis to date on the health status of pet rabbits under primary veterinary care. The most commonly diagnosed disorders at a fine precision were overgrown claw/nails, overgrown molar(s), perineal soiling, overgrown incisor(s) and ileus. The most prevalent disorder groups reported were dermatological, oral, gastrointestinal/abdominal, ocular and parasitic disorders. The median age at death for rabbits in this study was 4.3 years. Previous studies of the health of pet rabbits have relied on smaller numbers of animals or owner surveys.[11 12 15]

The most commonly recorded breed types were 'domestic', lop and Netherland dwarf. Given that 'domestic' is not a formally recognised rabbit breed, it appears that the true breed status is frequently loosely recorded in veterinary clinical records or may even be unknown by the owner or veterinary personnel. Lop rabbits were otherwise the most common formally recognised group of rabbits in the study, although the exact breed (or subtype) of lop was not specified in many cases, similar to other studies which also reported lop types as the most common type of pet rabbit.[11 14 15] Both lop and Netherland dwarf rabbits have been suggested to be predisposed to certain diseases due to their conformation,[4] although different lop breeds may have different predispositions. For example, entropion is suggested to be common in French lops,[27] whereas dwarf lops appear to be over-represented for dental

Table 3 Prevalence of the most common disorders at a *fine level of diagnostic precision* recorded in rabbits (n=2506) attending primary-care veterinary practices in England participating in the VetCompass programme from January 1, 2013 to December 31, 2013

Fine-level precision	Count	Overall (%)	95% CI	Female (%)	Male (%)	P value	Median age (years)
Overgrown claw/nails	400	16.0	14.5 to 17.5	14.3	17.4	0.041	3.6
Overgrown molar(s)	190	7.6	6.6 to 8.7	5.5	9.5	‹0.001	4.4
Perineal soiling	113	4.5	3.7 to 5.4	4.2	4.9	0.384	4.7
Overgrown incisor(s)	108	4.3	3.5 to 5.2	3.2	5.3	0.009	4.2
Ileus	104	4.2	3.4 to 5.0	4.3	4.1	0.811	3.3
Overweight/obesity	92	3.7	3.0 to 4.5	4.4	3.2	0.100	3.6
Anorexia	72	2.9	2.3 to 3.6	2.5	3.3	0.221	4.4
Myiasis (flystrike)	51	2.0	1.5 to 2.7	2.2	2.0	0.659	5.4
Nasolacrimal duct abnormality—dacryocystitis	50	2.0	1.5 to 2.6	1.5	2.5	0.086	4.7
Haircoat disorder—matted fur	46	1.8	1.3 to 2.4	2.1	1.7	0.394	4.5
Mite infestation	46	1.8	1.3 to 2.4	1.6	2.1	0.347	4.2
Underweight/weight loss	46	1.8	1.3 to 2.4	2.2	1.4	0.106	5.0
Diarrhoea	45	1.8	1.3 to 2.4	2.3	1.4	0.109	3.8
Skin disorder—dermatitis	45	1.8	1.3 to 2.4	2.1	1.6	0.317	4.8
Bite injury	43	1.7	1.2 to 2.3	1.5	1.8	0.559	1.6
Upper respiratory tract disorder	43	1.7	1.2 to 2.3	1.7	1.7	0.924	3.1
Dental disease—malocclusion	40	1.6	1.1 to 2.2	1.4	1.8	0.445	4.4
Head tilt	39	1.6	1.1 to 2.1	1.6	1.6	0.981	3.5
Conjunctivitis	37	1.5	1.0 to 2.0	1.3	1.6	0.602	5.5
Ocular discharge	35	1.4	1.0 to 1.9	1.4	1.4	0.976	4.4
Cheyletiellosis	31	1.2	0.8 to 1.8	1.1	1.4	0.414	4.0
Wound injury	29	1.2	0.8 to 1.7	1.2	1.1	0.819	2.1
Skin disorder—alopecia	28	1.1	0.7 to 1.6	1.3	0.9	0.315	2.4
Dental disease	25	1.0	0.6 to 1.5	0.4	1.5	0.009	4.9
Other	713	29.8					

The P value reflects testing of the prevalence difference between females and males using the chi-squared test.
CI, confidence interval.

Table 4 Prevalence of the most common disorders at a *grouped level of diagnostic precision* recorded in rabbits (n=2506) attending primary-care veterinary practices in England participating in the VetCompass programme from January 1, 2013 to December 31, 2013

Grouped level precision	Count	Overall (%)	95% CI	Female (%)	Male (%)	P value	Median age
Dermatological	505	20.2	18.6 to 21.8	19.2	21.1	0.234*	3.7
Oral	272	10.9	9.7 to 12.1	8.1	13.4	<0.001*	4.3
Gastrointestinal/abdominal	238	9.5	8.4 to 10.7	10.2	9.1	0.334*	4.0
Ocular	182	7.3	6.3 to 8.3	6.7	7.9	0.264*	5.0
Parasitic	178	7.1	6.1 to 8.2	6.7	7.6	0.401*	4.2
Behavioural	130	5.2	4.4 to 6.1	4.7	5.8	0.222*	4.1
Trauma	99	4.0	3.2 to 4.8	3.8	3.8	0.964*	2.0
Respiratory	93	3.7	3.0 to 4.5	3.3	4.1	0.259*	3.4
Overweight/obesity	92	3.7	3.0 to 4.5	4.4	3.2	0.100*	3.4
Neurological	74	3.0	2.3 to 3.7	3.6	2.5	0.098*	4.4
Iatrogenic	64	2.6	2.0 to 3.2	2.6	2.6	0.992*	2.4
Mass-associated	54	2.2	1.6 to 2.8	2.2	2.2	0.961*	5.8
Weight loss/underweight	51	2.0	1.5 to 2.7	2.3	1.7	0.250*	4.9
Abscess	47	1.9	1.4 to 2.5	1.9	1.9	0.965*	4.8
Renal/urinary	45	1.8	1.3 to 2.4	2.4	1.4	0.057*	4.2
Musculoskeletal	43	1.7	1.2 to 2.3	1.9	1.6	0.491*	5.9
Auditory	25	1.0	0.6 to 1.5	0.5	1.4	0.027*	5.5
Infection	19	0.8	0.5 to 1.2	1.0	0.6	0.295*	2.2
Cardiovascular	16	0.6	0.4 to 1.0	0.9	0.5	0.183*	5.5
Neoplasia	14	0.6	0.3 to 0.9	0.4	0.7	0.440*	8.6
Reproductive	6	0.2	0.1 to 0.5	0.5	0.1	0.100†	2.9
Hepatic	4	0.2	0.1 to 0.4	0.3	0.1	0.339†	2.5
Soft tissue	2	0.1	0.0 to 0.3	0.0	0.2	0.503†	5.6
Congenital	1	0.0	0.0 to 0.2	0.1	0.0	0.460†	1.0

The P value reflects testing of the prevalence difference between females and males using the chi-squared test or Fisher's exact test as indicated.
*Chi-squared test.
†Fisher's exact test.
CI, confidence interval.

disease.[15] Future studies focusing on specific rabbit breeds, similar to those that have been undertaken for dog breeds,[28–30] are therefore recommended to increase understanding of potential risk factors for different disorders within breed types.[15]

The median age of rabbits under veterinary care in this study was 3.2 years, consistent with previously reported demographics of pet rabbits attending veterinary practices.[31] Although the median age of males (3.3 years) was statistically higher than that of females (3.1 years), such a small difference is unlikely to be biologically or clinically significant, and highlights the importance of considering biological significance when interpreting epidemiological results.[32] Where data were recorded, the majority (72.4 per cent) of rabbits in this study population were recorded as neutered, but due to a high proportion of missing data regarding neuter status (80.3 per cent) this may not accurately reflect the wider pet population. Other studies have found only 46–59 per cent of rabbits are neutered,[2 11 31] so it is likely that data on rabbits that are actually under veterinary care may overestimate proportional neutering for the overall pet rabbit population in England. The high level of non-recording of neuter status suggests that this is a data field that veterinary practices could prioritise for completion in order to optimise their clinical record-keeping.

The current study reported a median age at death of 4.3 years with survival up to 14.4 years recorded. These findings support many textbooks that state that rabbits can live up to 10 years[33] and published studies based on owner surveys that have reported average longevities for pet rabbits from 4.2 to 5.4 years.[11 34] Considering that 34 per cent of rabbits are not currently registered with a veterinary practice,[2] the median age of death reported in this study may not completely reflect the wider UK rabbit population. The median age at death for males (5.2 years) was older than for females (3.7 years), but the high proportion of breeds recorded as domestic and the high level of missing data for neuter status precluded reliable deeper analyses to explore breed and neuter effects on survival.

Information on cause of death was available for 72.2 per cent of rabbits, with myiasis recorded as the most frequent cause of death. Other common causes of death included *Encephalitozoon cuniculi* infection, myxomatosis and bite injuries. These are all disease processes which could potentially be prevented by improved husbandry, vaccination and parasite control, and therefore highlight the value of regular veterinary care and developing suitable preventive medicine protocols.[35] Many of the common causes of death were recorded as clinical presentations (eg, anorexia, recumbency/collapse) that could be related to multiple underlying aetiologies rather than being

pathognomonic for specific underlying pathologies or diagnoses. A definitive biomedical diagnosis may not always be reached, or even needed, in primary-care practice where symptomatic treatment to resolve the presenting problem is often considered as an acceptable clinical goal.[21 36] Further research (including postmortem findings) would be needed to provide more information on the underlying disease processes leading to mortality in pet rabbits.

Dermatological disorders represented the most common disorder group in the current study, affecting 20.2 per cent of rabbits. This is consistent with data from other studies, both in the UK and abroad. A retrospective study in the USA reported that dermatological disease was present in 29 per cent of rabbits presented to the veterinary clinic,[37] while a survey of apparently healthy rabbits in Finland identified a prevalence of 16.8 per cent.[14] A survey of the conditions which UK vets perceived they commonly encountered also reported an estimated prevalence for skin conditions of 25.3 per cent in rabbits.[17]

Overgrown nails were the most common fine disorder in this study (16 per cent), similar to the 18.6 per cent reported in another UK study.[15] Although nail clipping is often seen as a routine procedure, nail elongation can indicate underlying husbandry deficits, including lack of space to exercise or inappropriate substrate. Alternatively, overgrown and deformed nails may be seen in older and/or overweight rabbits and may be associated with periods of excessive inactivity due to underlying disease.[38]

Perineal soiling was the second most common dermatological disorder (4.5 per cent) in this study, but this condition was not listed as a specific category in previous studies so the results of the current study cannot be directly compared. A UK-based survey did however indicate 'dirty bottoms' to be a common underlying health concern for owners, with 30.1 per cent reporting they had encountered this problem in their rabbits.[11] Perineal soiling is significant in pet rabbits because affected animals are subsequently predisposed to more serious disorders such as myiasis. The presence of soiling also often indicates underlying health issues such as obesity, pain, and urinary or gastrointestinal disease.[39] Rabbits with orodental disease have also been shown to be at increased risk of developing dermatological disorders later in life.[40]

Dental disorders are perceived by veterinarians as the most common disorder in pet rabbits,[14 15 17] and at the fine-level disorder overgrown molar(s) was the second most prevalent disorder. Oral disorders including overgrown incisors, overgrown molars and generalised dental disease were identified in 10.9 per cent of rabbits in this study. Another smaller study on common clinical presentations in small animal practice similarly reported overgrown incisors in 10.3 per cent and molar spurs in 4.1 per cent of rabbits.[16] However, despite these apparently high prevalence values, both studies may still underestimate the true prevalence of dental disease because surveys using endoscopic examination of the oral cavity or radiological screening have reported much higher prevalence estimates of 38.1–40.1 per cent.[14 41] In the present study, male rabbits had higher prevalence of dental disease than female rabbits. Previous evidence regarding sex as a risk factor for dental disease is conflicting. Two smaller studies identified no effect of sex on the presence of dental disease,[14 42] while another study identified male rabbits with higher risk of dental disease consistent with the current study.[43] Increased likelihood of developing overgrown molars in male compared to female rabbits may be, in part, explained by sexual dimorphism expressed in rabbits' masseter muscle fibres.[44] Interestingly a later study found that the differences between muscle fibres were largely driven by androgens and that castration of young adult males by six months of age prevented the development of this sexually dimorphic trait.[45] Ultimately the aetiology of dental disorders in rabbits appears to be multifactorial, with age, sex, breed, genetic disposition, husbandry and diet all playing contributory factors.[46] Further research is necessary to determine whether male rabbits are generally at an increased risk of dental disorders or whether the true risks are more nuanced than this.

Gastrointestinal/abdominal disorders, including ileus, were reported in 10.9 per cent of rabbits. Veterinarians perceive gastrointestinal disorders to be the third most common presentation, with an estimated prevalence of 15.2 per cent.[17] Ileus can, however, be caused by multiple factors, including pain, stress, inappropriate diet and dental disease.[47] The presence of ileus alone, therefore, does not necessarily signify a primary gastrointestinal or even abdominal disease. One previous study reported a prevalence of 25.1 per cent for ileus, with young adult rabbits, dwarf and lop breeds potentially being at increased risk.[48] The study was however performed at an exotics referral practice, so it may not necessarily reflect the whole UK pet rabbit population. Unfortunately, the current study did not include data on the types of diet fed to these rabbits, but a future study that includes this information would be very useful to explore dietary associations with gastrointestinal/abdominal disorders.

Ocular disorders were reported in 7.3 per cent of rabbits. The most common specific ocular disorders recorded were dacryocystitis, conjunctivitis or ocular discharge. Similarly, veterinarians perceive ocular disorders to be a fairly common presentation, with an estimated prevalence of 5.3 per cent.[17] Ocular discharge was noted as the most frequently presented problem in rabbits at 10.3 per cent in one study that reviewed commonly presented problems in small animal practice.[16] However, ocular discharge is a non-specific sign and may indicate a number of ophthalmic diseases including dacryocystitis and conjunctivitis, and also

potentially underlying dental or respiratory disease.[49] Further research is necessary to establish more details about these ocular disorders and any associated disease.

Parasitic disorders were reported in 7.1 per cent of rabbits. This prevalence value is difficult to directly compare with previous literature as other studies have tended to categorise conditions only into body systems or presenting signs rather than into specific aetiological causes. Myiasis was the most commonly recorded parasitic disorder, affecting 2 per cent of rabbits. The relatively high level of myiasis recorded under primary veterinary care may be promoted by an emotional reaction in owners that myiasis warrants more rapid veterinary care than other parasitic or general conditions. Previous studies have reported that 94.5 per cent of veterinary practices in England and Wales treated at least one case of myiasis, and electronic health records identified myiasis in 0.6 per cent of consults.[50 51] Myiasis is a significant welfare concern as mortality rates with this condition appear high, with 44.7 per cent of cases recorded as euthanased or dying from the condition.[50]

There were some limitations to the current study. The practices contributing data were a convenience sample based on practices participating in VetCompass. Consequently, their geographical location, client demography and clinical approaches may not be representative of all veterinary practices in England. Associations between breed types and disorder prevalence were not assessed in the current study because the study was underpowered for such analyses. There was a high proportion of missing data for neuter status and bodyweight, so the results reported for these variables should be treated with caution. The opportunity for clinicians to document a more thorough demography for rabbits in terms of breed information, neuter status and bodyweight (or body condition) is clear. This information would aid future research but is also of immediate clinical significance when considering differential diagnoses and disease risk.

The most common causes of death recorded appear to be end-stage clinical signs (eg, myiasis or collapse/recumbency) that are secondary to underlying disease processes. The analyses did not attempt to correct for multiple comparisons so the P values should be interpreted as exploratory rather than confirmatory in nature.[52] No attempts were made by the researchers to second-guess the underlying disorders in cases where only clinical signs were listed. This suggests the importance of approaching preventive or routine veterinary visits in rabbits with heightened vigilance for insidious signs that are unapparent to owners but that can indicate unrecognised disease processes. Fine-level disorders can be grouped according to many different schemes, such as body location, body system and pathophysiology.[20] The current study elected to group according to broader categories as typically used by veterinary practitioners, but alternative grouping methods may have yielded differing conclusions. Finally, this study only included data on those rabbits presented to a veterinary practice. Therefore, while the authors cannot assume that the findings will generalise equally to all pet rabbits in England, the findings from this study together with those from other studies can be combined in order to increase understanding of common disorders in this species.

Conclusion

This study represents the largest practice-based study to date of rabbit health in England. The relatively low median age of death of 4.3 years in rabbits that attended veterinary practices was identified. Myiasis, anorexia, recumbency and ileus were recorded as the most common reasons for death or euthanasia. Dermatological, oral, gastrointestinal and ocular disorder groups were commonly recorded. The most frequent individual conditions reported included nail conditions, dental disease, perineal soiling, ileus, overweight and anorexia. This study adds to the limited evidence base on rabbit health and provides veterinary clinicians with a clearer understanding of the common conditions recorded in primary-care veterinary practice in England. This information can guide both further professional education and research priorities for improved rabbit health.

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References

1 PFMA. The Pet Food Manufacturers' Association 'Statistics': The Pet Food Manufacturers' Association, 2018. Available: https://www.pfma.org.uk/statistics
2 PDSA. Paw PDSA animal wellbeing report 2018, 2018.
3 British Rabbit Council. Breed standards Newark. Notts: The British Rabbit Council, 2017. https://thebritishrabbitcouncil.org/standards.htm
4 Varga M. Textbook of rabbit medicine. 2nd edn. Butterworth Heinemann: Elsevier Ltd, 2014.
5 Fox RR, Crary DD. Mandibular prognathism in the rabbit. genetic studies. *J Hered* 1971;62:23–7.
6 Greene HSN. Uterine adenomata in the rabbit. *The Journal of Experimental Medicine* 1941;73:273.
7 Kunstýř I, Naumann S. Head tilt in rabbits caused by pasteurellosis and encephalitozoonosis. *Lab Anim* 1985;19:208–13.
8 Johnson JC, Burn CC. Lop-eared rabbits have more aural and dental problems than erect-eared rabbits: a rescue population study. *bioRxiv* 2019:1–27.

9 Lehmann M. Social behaviour in young domestic rabbits under semi-natural conditions. *Appl Anim Behav Sci* 1991;32:269–92.
10 PDSA. PDSA animal wellbeing report 2011. PDSA, 2011.
11 Rooney NJ, Blackwell EJ, Mullan SM, *et al*. The current state of welfare, housing and husbandry of the English PET rabbit population. *BMC Res Notes* 2014;7:942.
12 Edgar JL, Mullan SM. Knowledge and attitudes of 52 UK PET rabbit owners at the point of sale. *Veterinary Record* 2011;168.
13 Welch T, Coe JB, Niel L, *et al*. A survey exploring factors associated with 2890 companion-rabbit owners' knowledge of rabbit care and the neuter status of their companion rabbit. *Prev Vet Med* 2017;137:13–23.
14 Mäkitaipale J, Harcourt-Brown FM, Laitinen-Vapaavuori O. Health survey of 167 pet rabbits (*Oryctolagus cuniculus*) in Finland. *Veterinary Record* 2015;177.
15 Mullan SM, Main DCJ. Survey of the husbandry, health and welfare of 102 PET rabbits. *Veterinary Record* 2006;159:103–9.
16 Robinson NJ, Dean RS, Cobb M, *et al*. Investigating common clinical presentations in first opinion small animal consultations using direct observation. *Veterinary Record* 2015;176.
17 Robinson N, Lyons E, Grindlay D, *et al*. Veterinarian Nominated common conditions of rabbits and guinea pigs compared with published literature. *Veterinary Sciences* 2017;4.
18 McGreevy PD. Breeding for quality of life. *Anim Welfare* 2007;16:125–8.
19 O'Neill DG, Church DB, McGreevy PD, *et al*. Prevalence of disorders recorded in cats attending primary-care veterinary practices in England. *The Veterinary Journal* 2014;202:286–91.
20 O'Neill DG, Church DB, McGreevy PD, *et al*. Prevalence of disorders recorded in dogs attending primary-care veterinary practices in England. *PLoS One* 2014;9:e90501–16.
21 May S. Towards a scholarship of primary health care. *Veterinary Record* 2015;176:677–82.
22 VetCompass. VetCompass™ programme London: RVC electronic media unit, 2019. Available: http://www.rvc.ac.uk/VetCOMPASS/
23 Pearce N. Classification of epidemiological study designs. *Int J Epidemiol* 2012;41:393–7.
24 Epi Info 7 CDC. Centers for disease control and prevention (US): introducing epi Info 7 Atlanta. Georgia: CDC, 2019. http://wwwn.cdc.gov/epiinfo/7
25 Kirkwood BR, Sterne JAC. Essential medical statistics. 2nd ed. Oxford: Blackwell Science, 2003.
26 Agresti A, Coull BA. Approximate is better than "exact" for interval estimation of binomial proportions. *The American Statistician* 1998;52:119–26.
27 Holmberg BJ, Slatter DH. Ophthalmology of Exotic Pets. In: Maggs DJ, Miller PE, Ofri R, eds. Slatter's fundamentals of veterinary ophthalmology. Philadelphia, Pa; London: Elsevier Saunders, 2008:427–41.
28 O'Neill DG, Baral L, Church DB, *et al*. Demography and disorders of the French Bulldog population under primary veterinary care in the UK in 2013. *Canine Genetics and Epidemiology* 2018;5.
29 O'Neill DG, Coulson NR, Church DB, *et al*. Demography and disorders of German Shepherd dogs under primary veterinary care in the UK. *Canine Genetics and Epidemiology* 2017;4. 1.
30 O'Neill DG, Seah WY, Church DB, *et al*. Rottweilers under primary veterinary care in the UK: demography, mortality and disorders. *Canine Genetics and Epidemiology* 2017;4.
31 Sánchez-Vizcaíno F, Noble P-JM, Jones PH, *et al*. Demographics of dogs, cats, and rabbits attending veterinary practices in Great Britain as recorded in their electronic health records. *BMC Vet Res* 2017;13:218.
32 Nakagawa S, Cuthill IC. Effect size, confidence interval and statistical significance: a practical guide for biologists. *Biological Reviews* 2007;82:591–605.
33 Lennox AM. Care of the geriatric rabbit. *Veterinary Clinics of North America: Exotic Animal Practice* 2010;13:123–33.
34 Schepers F, Koene P, Beerda B. Welfare assessment in PET rabbits. *Anim Welfare* 2009;18:477–85.
35 Sayers I. Approach to preventive health care and welfare in rabbits. *In Pract* 2010;32:190–8.
36 Heneghan C, Glasziou P, Thompson M, *et al*. Diagnostic strategies used in primary care. *BMJ* 2009;338:b946–b.
37 Snook TS, White SD, Hawkins MG, *et al*. Skin diseases in PET rabbits: a retrospective study of 334 cases seen at the University of California at Davis, USA (1984-2004). *Vet Dermatol* 2013;24:613–e148.
38 Meredith A, Lord B. BSAVA manual of rabbit medicine. Wiley, 2014.
39 Cousquer G. Veterinary care of rabbits with myiasis. *In Pract* 2006;28:342–9.
40 d'Ovidio D, Santoro D. Orodental diseases and dermatological disorders are highly associated in PET rabbits: a case-control study. *Vet Dermatol* 2013;24:531–e125.
41 Jekl V, Hauptman K, Knotek Z. Quantitative and qualitative assessments of intraoral lesions in 180 small herbivorous mammals. *Vet Rec* 2008;162:442–9.
42 Harcourt-Brown FM, Baker SJ. Parathyroid hormone, haematological and biochemical parameters in relation to dental disease and husbandry in rabbits. *J Small Anim Pract* 2001;42:130–6.
43 Siriporn B, Weerakhun S. A study of risk factors, clinical signs and radiographic findings in relation to dental diseases of domestic rabbits. *KKU Veterinary Journal* 2014;24:201–13.
44 d'Albis A, Couteaux R, Janmot C, *et al*. Opposite regulations by androgenic and thyroid hormones of V1 myosin expression in the two types of rabbit striated muscle: skeletal and cardiac. *FEBS Lett* 1993;318:53–6.
45 Eason JM, Schwartz G, Shirley KA, *et al*. Investigation of sexual dimorphism in the rabbit masseter muscle showing different effects of androgen deprivation in adult and young adult animals. *Arch Oral Biol* 2000;45:683–90.
46 Harcourt-Brown F. Dental disease in PET rabbits: 1. normal dentition, pathogenesis and aetiology. *In Pract* 2009;31:370–9.
47 DeCubellis J, Graham J. Gastrointestinal disease in guinea pigs and rabbits. *Veterinary Clinics of North America: Exotic Animal Practice* 2013;16:421–35.
48 Huynh M, Vilmouth S, Gonzalez MS, *et al*. Retrospective cohort study of gastrointestinal stasis in PET rabbits. *Veterinary Record* 2014;175.
49 Florin M, Rusanen E, Haessig M, *et al*. Clinical presentation, treatment, and outcome of dacryocystitis in rabbits: a retrospective study of 28 cases (2003-2007). *Vet Ophthalmol* 2009;12:350–6.
50 Turner R, Arsevska E, Brant B, *et al*. Risk factors for cutaneous myiasis (blowfly strike) in PET rabbits in Great Britain based on text-mining veterinary electronic health records. *Prev Vet Med* 2018;153:77–83.
51 Bisdorff B, Wall R. Blowfly strike prevalence in domestic rabbits in Southwest England and Wales. *Vet Parasitol* 2006;141:150–5.
52 Bender R, Lange S. Adjusting for multiple testing—when and how? *J Clin Epidemiol* 2001;54:343–9.