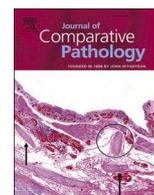




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## A retrospective study (2019-2024) of neoplastic and non-neoplastic lesions in biopsy samples from exotic pet mammals in Hong Kong

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## ABSTRACT

This retrospective study analysed pathological findings in tissue biopsies from eight exotic pet mammal species submitted to the CityU Veterinary Diagnostic Laboratory in Hong Kong between January 2019 and December 2024. Tissue biopsies were submitted from 287 rabbits, 161 hamsters, 131 hedgehogs, 64 guinea pigs, 22 chinchillas, 20 rats, seven mice and six ferrets. Across all investigated species, both neoplastic and non-neoplastic lesions were prevalent with species-specific tendencies in affected organ system. Skin and soft tissues, along with the reproductive system, were the most affected organ system in all investigated species. Except for chinchillas, neoplastic lesions outnumbered non-neoplastic lesions in all studied species. Adenocarcinoma (15.2%) mostly of the uterus and mammary gland was the most commonly diagnosed lesion in rabbits followed by trichoblastoma (14.5%). Adenoma (14.6%), mostly of the mammary gland, was the most frequently submitted lesion from hamsters, followed by lymphoma (9.8%). Sarcomas of uncertain differentiation were the most prevalent lesions in hedgehogs (21.4%) and were primarily cutaneous and uterine sarcomas, while cystic endometrial hyperplasia (CEH) ranked second (15.3%). In guinea pigs, CEH (21.5%) was the most commonly identified pathology followed by mammary adenoma (13.8%). The reproductive system accounted for more than half of the lesions diagnosed in chinchillas with CEH and endometritis being the most prevalent lesions, each representing 18.2% of submitted biopsies from chinchillas. Mammary gland fibroadenoma was the most frequent diagnosis in rats (55%) and equal in frequency with adenocarcinoma in mice, each representing 25% of submitted biopsies. Ferrets had seven distinct diagnoses. These findings emphasize the significance of reproductive and integumentary health in exotic pet mammals and reveal species-specific disease patterns critical for diagnosis and preventive care.

### 1. Introduction

Exotic pet mammals, including a wide range of species from small rodents to ferrets, and hedgehogs have become popular household companion animals worldwide [1]. This is particularly true in densely populated urban regions such as Hong Kong, where various factors such

as limited living spaces, distinct aesthetic appeal and perceived ease of care can favour keeping exotic pets compared to traditional ones [2]. However, the increasing ownership of these animals underscores the significance of understanding and addressing their specific health challenges.

Neoplastic and non-neoplastic lesions represent a wide range of

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pathological diseases that can significantly affect the health and welfare of exotic pet mammals. Neoplastic diseases, including malignant and benign tumours, are increasingly recognized as a common clinical entity in various exotic small mammals, with research demonstrating a rising prevalence and a decreasing average age of diagnosis [3–5]. Concurrently, non-neoplastic lesions, including inflammatory processes and degenerative changes, also contribute substantially to morbidity in these species [6]. Accurate diagnosis and characterization of these lesions is primarily dependent on histological analysis of biopsy specimens and is paramount for appropriate therapy and prognosis.

In recent years, millions of live exotic animals have been imported into Hong Kong, contributing to a significant increase in the exotic pet trade [2] and underscoring the critical need for comprehensive veterinary data specific to the region. While some localized studies have begun to shed light on specific health issues in certain exotic pet populations within Hong Kong [4], a thorough, retrospective analysis of pathological findings across a wider spectrum of exotic pet mammals is currently lacking.

To address this knowledge gap, this retrospective study analyses 707 histopathological reports from eight different exotic pet mammal species (rabbits, hamsters, hedgehogs, guinea pigs, chinchillas, rats, mice and ferrets) submitted to the City University of Hong Kong Veterinary Diagnostic Laboratory (CityU VDL) between January 2019 and December 2024. By systematically reviewing these cases, this study aims to characterize the spectrum and frequency of neoplastic and non-neoplastic lesions observed across these species. These findings enhance understanding of the disease landscape in exotic pet mammals in Hong Kong and provide valuable information to improve diagnostic accuracy and support future research that may guide treatment decisions and zoonotic risk assessment.

## 2. Materials and methods

### 2.1. Case selection

In this retrospective study, histopathological reports of biopsy samples from live exotic pet mammals (including rabbits, hamsters, hedgehogs, guinea pigs, chinchillas, rats, mice and ferrets) submitted by veterinarians in Hong Kong to CityU VDL between January 2019 and December 2024 were reviewed. Reports involving laboratory exotic mammals and all necropsy submissions whether as whole carcasses or as individual tissue samples were excluded. Extracted data included species, breed, sex, neutering status, age at sampling, lesion location, affected organ or tissue and histopathological diagnosis of both neoplastic and non-neoplastic lesions.

### 2.2. Histological examination

Tissue samples were fixed in 10% neutral-buffered formalin immediately after collection at the referring veterinary clinic and subsequently submitted to CityU VDL. After fixation, specimens underwent gross examination, and representative sections were subjected to routine histological processing, embedding in paraffin wax and sections stained with haematoxylin and eosin (HE). Special stains were applied as needed: Gram or Giemsa for bacterial evaluation; periodic acid–Schiff (PAS) or Grocott methenamine silver (GMS) for fungal detection; and Ziehl–Neelsen (ZN) for mycobacteria. Cases were diagnosed by registered specialist veterinary pathologists, following the guidelines of the International Histological Classification of Tumors of Domestic Animals [7–9].

### 2.3. Statistical analysis

Clinical data were extracted from each histopathological report and compiled into an Excel spreadsheet. Duplicate entries and cases lacking a definitive diagnosis were excluded. Lesions were classified as either

neoplastic or non-neoplastic, and neoplasms were further categorized as benign or malignant. All lesions were subsequently grouped according to the affected organ and body system. Descriptive statistics, including the number and proportion of each lesion type with corresponding 95% confidence intervals, were calculated using Stata version 19 (StataCorp, [www.stata.com](http://www.stata.com)). Data visualization was conducted using R software (version 4.3.1; R Core Team, [www.r-project.org](http://www.r-project.org)).

## 3. Results

### 3.1. Study population

A total of 707 histopathological reports from 698 animals representing eight different exotic pet mammalian species were reviewed. These cases were submitted to the CityU VDL between January 2019 and December 2024 by 31 different veterinary hospitals and clinics across Hong Kong. The exotic pet animal species studied included rabbits, hamsters, hedgehogs, guinea pigs, chinchillas, rats, mice and ferrets. The number of animals per species, the corresponding total number of lesions and their classification as neoplastic or non-neoplastic, with neoplastic lesions further classified into benign or malignant, are summarized in Table 1. The distribution of cases over age and a graphical presentation of the most frequently recorded lesions in each species are illustrated in Figs. 1 and 2, respectively.

### 3.2. Histopathological lesions

#### 3.2.1. Rabbits

A total of 290 biopsy specimens were obtained from 287 rabbits. Three rabbits were diagnosed with two distinct neoplasms each: two had coexisting, non-identical tumours within the same organ (one with uterine adenocarcinoma and leiomyosarcoma, the other with testicular seminoma and granular cell tumour) and one had neoplasms in two different organs (uterine adenocarcinoma and cutaneous trichoblastoma). Rabbits in this study ranged in age from 0.3 to 14 years old, with the peak incidence of lesions occurring around 6.6 years. Of the 287 rabbits, 144 (50.2%) were females (70 [48.6%] spayed), 139 (48.4%) were males (63 [45.3%] castrated) and sex information was not available for four (1.4%) rabbits.

Of the 290 specimens, 179 (61.7%) were diagnosed as neoplastic and 111 (38.3%) as non-neoplastic lesions. Among the neoplastic cases, approximately half were benign ( $n = 90$ ; 31% of all lesions), and the other half malignant ( $n = 89$ ; 30.7% of all lesions). The most commonly affected organ system was skin and soft tissues ( $n = 106$ ; 36.6%), followed by the reproductive tract ( $n = 77$ ; 26.5%), the gastrointestinal tract ( $n = 45$ ; 15.5%), the mammary gland ( $n = 24$ ; 8.3%), the haematolymphoid system ( $n = 13$ ; 4.5%) and the musculoskeletal system ( $n = 12$ ; 4.1%) (Table 2).

Adenocarcinoma was the most frequently diagnosed lesion in rabbits ( $n = 44$ ; 15.2%), which primarily included uterine adenocarcinomas ( $n = 30$ ; 10.3%) and mammary adenocarcinomas ( $n = 12$ ; 4.1%; Fig. 3A and B). The second most frequently diagnosed lesion was trichoblastoma ( $n = 42$ ; 14.5%; Fig. 3C) followed by dermatitis ( $n = 15$ ; 5.2%), cystic endometrial hyperplasia (CEH;  $n = 15$ ; 5.2%; Fig. 3D), sarcoma ( $n = 14$ ; 4.8%; Fig. 3E and F), thymoma ( $n = 12$ ; 4.1%) and interstitial cell tumour ( $n = 12$ ; 4.1%). Polyps were reported in 11 cases (3.8%), of which 10 were detected in the gastrointestinal tract and one in the uterus. Liver torsion was diagnosed in 10 rabbits (3.4%). Lymphoma was diagnosed in five cases (1.7%): four located in the skin and soft tissues and one in the liver.

#### 3.2.2. Hamster

Due to inconsistent species identification in histopathology submission forms, all hamster species were grouped into a single category for the purposes of this analysis. A total of 164 biopsy specimens were collected from 161 hamsters. Two hamsters had multiple distinct

**Table 1**  
Distribution of neoplastic and non-neoplastic lesions in exotic pet mammals in Hong Kong (2019–2024).

Species	Total no. of animals	Total no. of lesions	Number (%) of lesions			
			Neoplastic	Non-neoplastic	Benign	Malignant
Rabbits	287	290	179 (61.7)	111 (38.3)	90 (31.0)	89 (30.7)
Hamster	161	164	126 (76.8)	38 (23.2)	63 (38.4)	63 (38.4)
Hedgehog	131	131	76 (58.0)	55 (42.0)	15 (11.4)	61 (46.6)
Guinea pig	64	65	42 (64.6)	23 (35.4)	33 (50.8)	9 (13.8)
Chinchilla	22	22	7 (31.8)	15 (68.2)	2 (9.1)	5 (22.7)
Rats	20	20	18 (90.0)	2 (10.0)	15 (75.0)	3 (15.0)
Mice	7	8	6 (75.0)	2 (25.0)	2 (25.0)	4 (50.0)
Ferrets	6	7	6 (85.7)	1 (14.3)	5 (71.4)	1 (14.3)
<b>Total</b>	<b>698</b>	<b>707</b>	<b>460 (65.1)</b>	<b>247 (34.9)</b>	<b>225 (31.8)</b>	<b>235 (33.2)</b>

lesions: one had uterine CEH, an ovarian fibroma and a splenic haemangiosarcoma, while the other had a facial squamous cell carcinoma and a trichoblastoma on one limb. The age of hamsters in this study ranged from 0.3 to 4.9 years old, with the peak incidence of lesions occurring around 1.4 years old.

Among the 161 hamsters, 106 (65.8%) were females (seven [6.6%] spayed), 54 (33.5%) were males (two [3.7%] castrated) and one (0.6%) hamster's sex was unknown. Out of the 164 specimens, 126 (76.8%) were classified as neoplastic and 38 (23.2%) as non-neoplastic lesions. Exactly half ( $n = 63$ ; 50%) of the neoplastic lesions were benign, and the other half ( $n = 63$ ; 50%) were malignant. The skin and soft tissues were the most affected organ system ( $n = 83$ ; 50.6%), followed by the reproductive tract ( $n = 37$ ; 22.6%) and the mammary gland ( $n = 26$ ; 15.9%). Lesions involving the haematolymphoid, gastrointestinal and musculoskeletal systems were less common, each accounting for 2.4% of the lesions (Table 3).

Adenoma was the most frequently diagnosed lesion in hamsters ( $n = 24$ ; 14.6%), with the majority occurring in the mammary gland ( $n = 15$ ; 9.1%; Fig. 4A). Lymphoma was the second most frequently diagnosed lesion in hamsters ( $n = 16$ ; 9.8%), primarily found in the skin and soft tissues ( $n = 13$ ; 81.3%; Fig. 4B), with additional cases in lymph nodes ( $n = 2$ ) and one testicular lymphoma in a Syrian hamster. Papilloma was the third most common detected lesion ( $n = 12$ ; 7.3%; Fig. 4C and D), including seven in the vagina, two in the vulva, two in the ear pinna and one on the eyelid. In addition, fibrosarcoma and adenocarcinoma were equally represented ( $n = 11$  each; 6.7%). Fibrosarcomas were predominantly cutaneous, involving different topographical locations, such as limbs, ear pinna and abdominal soft tissue ( $n = 8$ ; 4.9%), with two additional cases in the musculoskeletal system and one case in the mammary gland. Adenocarcinomas were mammary ( $n = 9$ ; 5.5%) and uterine ( $n = 2$ ; 1.2%).

Among non-neoplastic lesions, dermatitis and pyometra were the most common, each diagnosed in 10 hamsters (6.1% of all lesions), followed by CEH in six (3.7%) hamsters. Neoplastic lesions included squamous cell carcinoma and myxosarcoma (six cases each; 3.7%), as well as melanoma, trichoblastoma, mast cell tumour and plasma cell tumour ( $n = 5$ ; 3%; Fig. 4E). Trichoepithelioma was identified in three hamsters (1.8%), whereas demodicosis was detected in two hamsters (1.2%; Fig. 4F).

### 3.2.3. Hedgehog

Data were collected from 131 hedgehogs amounting to 131 biopsy specimens. The average age of the sampled hedgehogs was 2.9 years, ranging from 0.2 to 5.6 years. Notably, almost three quarters of the submitted specimens were from female hedgehogs ( $n = 97$ ; 74%; 23 spayed), and about one quarter ( $n = 34$ ; 26%) were from males, of which only one was castrated. Among the total cases, 76 (58%) were classified as neoplastic and 55 (42%) were non-neoplastic. Of the neoplastic lesions, 15 (11.1%) were benign and 61 (46.6%) were malignant neoplasms. The most affected organ system in hedgehogs was the reproductive system ( $n = 52$ ; 39.7%), followed by the skin and soft tissues ( $n = 39$ ; 29.8%), the gastrointestinal tract ( $n = 24$ ; 18.3%) and

the mammary gland ( $n = 12$ ; 9.2%) (Table 4).

The most commonly identified lesion in hedgehogs was sarcoma of uncertain differentiation ( $n = 28$ ; 21.4%), which predominantly involved the skin ( $n = 16$ ; Fig. 5A) and uterus ( $n = 10$ ). These 28 sarcomas excluded other identified sarcomas of known origin comprising four uterine leiomyosarcomas, two fibrosarcomas (one mammary and one cutaneous), two cutaneous histiocytic sarcomas, one cutaneous myxosarcoma and one cutaneous haemangiosarcoma. The second identified lesion in hedgehogs was CEH ( $n = 20$ ; 15.3%; Fig. 5B), followed by gingivitis ( $n = 16$ ; 12.2%) and adenocarcinoma ( $n = 9$ ; 6.9%). Adenocarcinomas were mainly of mammary origin ( $n = 6$ ), with two uterine and one salivary gland adenocarcinoma. Mast cell tumours ( $n = 7$ ; 5.3%; Fig. 5C) were identified and included three malignant and four benign cases. Uterine leiomyoma was diagnosed in four (3.1%) hedgehogs. Other detected neoplasms included two oral squamous cell carcinomas, two ovarian granulosa cell tumours (Fig. 5D), two lymphomas, one basal cell carcinoma, one tibial osteosarcoma, one teratoma and one trichoblastoma.

### 3.2.4. Guinea pig

A total of 65 biopsy specimens were collected from 64 guinea pigs. Among the 64 animals studied, one had two non-neoplastic lesions: CEH in the uterus and a cystic rete ovarian condition. The age of guinea pigs at the time of submission ranged from 0.6 to 5.8 years old, with a mean age of 3.5 years. Received specimens were from 38 (59.4%) female guinea pigs (four spayed) and 26 (40.6%) male guinea pigs (four castrated).

Of the 65 diagnosed lesions, 42 (64.6%) were classified as neoplastic and 23 (35.4%) as non-neoplastic lesions. The majority of the neoplastic lesions were benign ( $n = 33$ ). The reproductive system was the most frequently affected organ system in guinea pigs ( $n = 23$ ; 35.4%), followed by the skin and soft tissues ( $n = 19$ ; 29.2%) and the mammary gland ( $n = 17$ ; 26.2%). Other organs systems, including the haematolymphoid, urinary, musculoskeletal, special senses, cardiovascular and endocrine systems, were each represented by one lesion (Table 5).

CEH was the most frequently diagnosed lesion in guinea pigs ( $n = 14$ ; 21.5%), followed by mammary adenomas ( $n = 9$ ; 13.8%; Fig. 6A). Trichofolliculoma (Fig. 6B) and lipoma were each diagnosed in seven (10.8%) cases, making them the third most common diagnoses in guinea pigs, followed by uterine leiomyoma ( $n = 5$ ; 7.7%) and mammary adenocarcinoma ( $n = 4$ ; 6.2%). Among the lipomas, three were found in the mammary gland, while the others were found in the abdomen and subcutaneous tissues. Furthermore, two liposarcomas (Fig. 6C) were identified: one located in the subcutaneous tissue near the elbow and one in the soft tissue of the inguinal area. Other sarcomas were identified, including one splenic haemangiosarcoma (Fig. 6D) and one cutaneous fibrosarcoma.

### 3.2.5. Chinchilla

Twenty-two biopsy specimens from 22 chinchillas were submitted, with a mean age of 3.5 years and an age range of 0.7 to 16.5 years. Of these, 16 (72.7%) were female (two spayed) and the remaining six

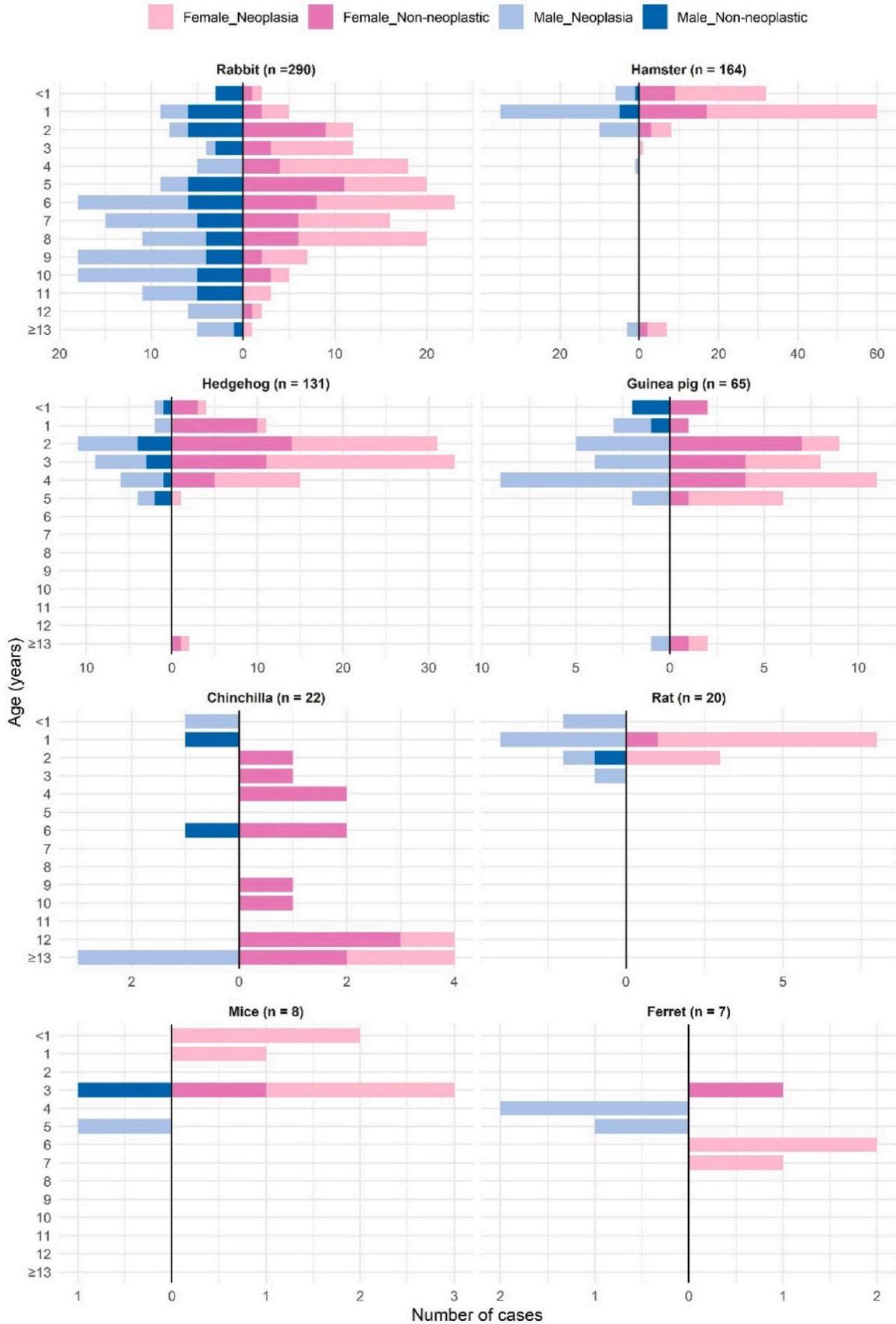


Fig. 1. Demographics of lesions, including age and sex, of exotic pet mammals (n = 698) with neoplastic and non-neoplastic lesions (n = 707) submitted to the City University of Hong Kong Veterinary Diagnostic Laboratory between 2019 and 2024.





Fig. 2. (continued).

Table 2

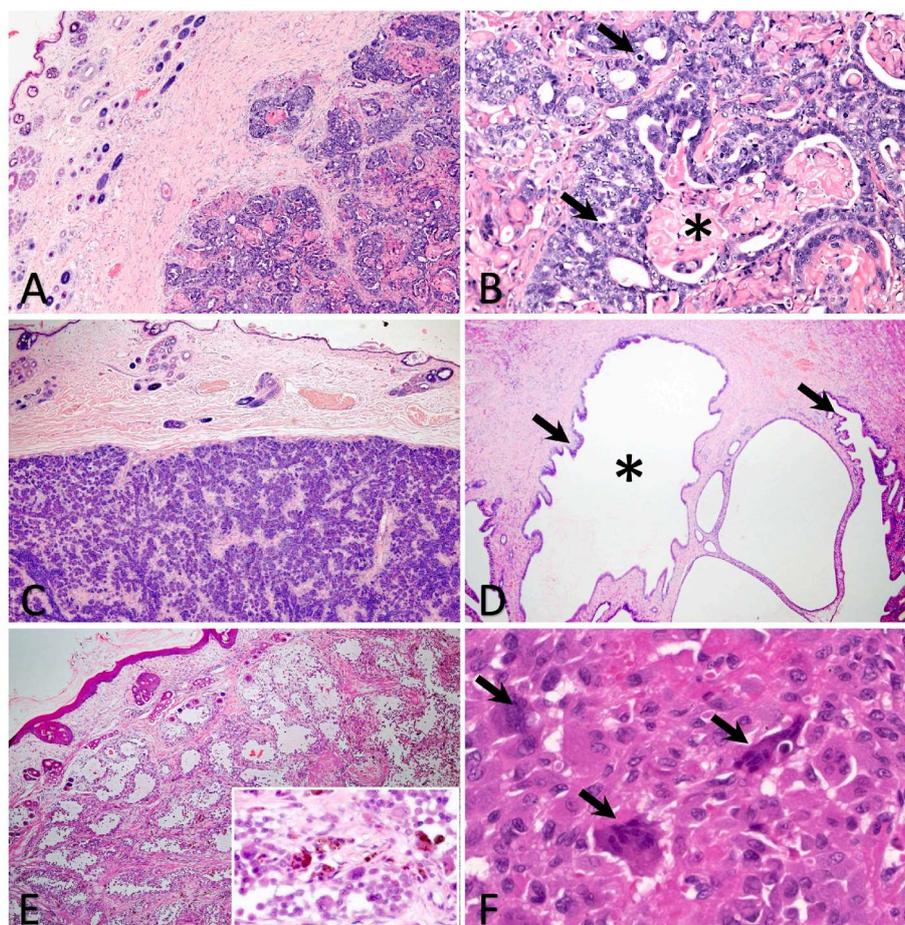
Frequency of neoplastic and non-neoplastic lesions in exotic pet rabbits in Hong Kong (2019–2024).

Organ system	No. (%) of lesions			Age (years)		Sex		
	All	Neoplastic	Non-neoplastic	Mean	Range	Female	Male	Unknown
Skin and soft tissue	106 (36.6)	74 (41.3)	32 (28.8)	6.9	0.83–14.0	38	66	2
Reproductive tract	77 (26.5)	54 (30.1)	23 (20.7)	6.4	0.3–14.0	54	23	0
Gastrointestinal tract	45 (15.5)	8 (4.5)	37 (33.3)	5.6	1.0–14.0	22	22	1
Mammary gland	24 (8.3)	16 (8.9)	8 (7.2)	6.7	1.1–11.8	16	8	0
Haematolymphoid system	13 (4.5)	13 (7.3)	0	7.5	1.1–11.0	6	7	0
Musculoskeletal system	12 (4.1)	12 (6.7)	0	10.1	5.0–12.6	4	8	0
Urinary system	8 (2.8)	1 (0.6)	7 (6.4)	6.8	0.3–11.0	3	4	1
Peritoneum	3 (1.0)	1 (0.6)	2 (1.8)	6.0	2.9–9.0	1	2	0
Special sense	2 (0.7)	0	2 (1.8)	6.3	2.2–10.4	2	0	0
<b>Total</b>	<b>290</b>	<b>179 (61.7)</b>	<b>111 (38.3)</b>	<b>6.6</b>	<b>0.3–14.0</b>	<b>146</b>	<b>140</b>	<b>4</b>

and a sarcoma. Of the eight lesions, six (75%) were neoplastic and two (25%) were non-neoplastic. The mammary gland was the most commonly affected organ (n = 5; 62.5%), including two adenocarcinomas, two fibroadenomas and one sarcoma (Fig. 7C). The skin and soft tissues was represented by two lesions (25%): a cutaneous

haemangiosarcoma and a cutaneous polyp. The digestive system was represented by a single case of gingivitis (12.5%).

During the study period, seven biopsy specimens were submitted from six ferrets. One ferret had two distinct diagnoses: a cutaneous adenoma and a musculoskeletal chordoma. Of the seven specimens, only



**Fig. 3.** Frequent histopathological lesions, rabbits. (A, B) Mammary gland, Adenocarcinoma. Neoplastic epithelial cells show moderate anisocytosis and anisokaryosis with squamous metaplasia (asterisk) and mitotic figures (arrows). HE.  $\times 40$  and  $\times 200$  respectively. (C) Skin, Trichoblastoma. Well-demarcated, non-encapsulated highly cellular epithelial neoplasm with neoplastic cells arranged in monotonous trabeculae and nests supported by a fibrous stroma. HE.  $\times 40$  (D) Uterus, Cystic endometrial hyperplasia. Endometrial glands are ectatic and hyperplastic (asterisk) with attenuated or hyperplastic columnar epithelium occasionally thrown into papillary projections (arrows) HE.  $\times 40$ . (E, F) Skin, Giant cell sarcoma. Neoplastic cells form interwoven bundles of spindle cells, interspersed with polygonal cells occasionally phagocytosing brown haemosiderin pigment (inset). In the most cellular parts of the neoplasm, multinucleated giant cells (arrows) and epithelioid cells are predominant. HE.  $\times 40$  and  $\times 400$  respectively and inset in E is  $\times 400$ .

**Table 3**

Frequency of neoplastic and non-neoplastic lesions in exotic pet hamster in Hong Kong (2019–2024).

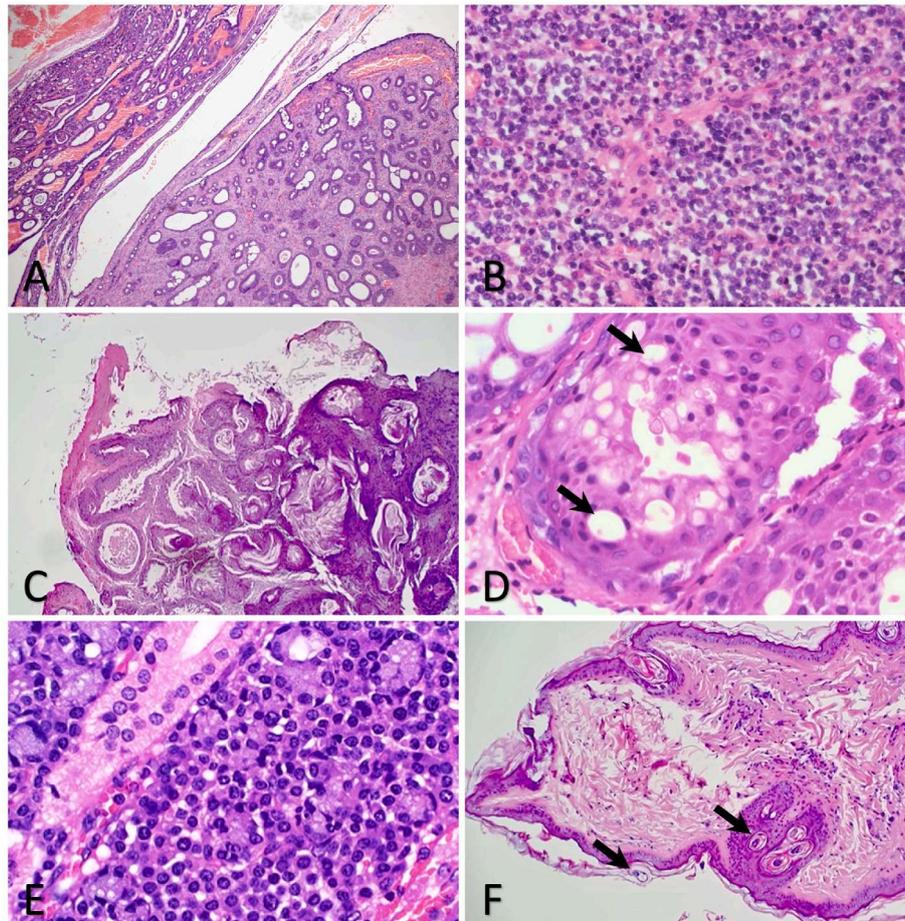
Organ system	No. (%) of lesions			Age (years)		Sex		
	All	Neoplastic	Non-neoplastic	Mean	Range	Female	Male	Unknown
Skin and soft tissue	83 (50.6)	71 (56.3)	12 (31.6)	1.4	0.5–4.9	40	42	1
Reproductive tract	37 (22.6)	17 (13.5)	20 (52.6)	1.4	0.5–3.1	33	4	0
Mammary gland	26 (15.9)	25 (19.8)	1 (2.6)	1.0	0.6–2.2	25	1	0
Gastrointestinal tract	4 (2.4)	3 (2.4)	1 (2.6)	1.3	1.0–1.7	2	2	0
Haematolymphoid system	4 (2.4)	4 (3.2)	0	1.1	0.3–2.0	3	1	0
Musculoskeletal system	4 (2.4)	3 (2.4)	1 (2.6)	1.4	0.7–2.1	2	2	0
Special sense	3 (1.8)	2 (1.6)	1 (2.6)	0.8	0.5–1.5	1	2	0
Peritoneum	2 (1.2)	0	2 (5.3)	0.9	0.8–1.0	2	0	0
Urinary system	1 (0.6)	1 (0.8)	0	1.9	–	0	1	0
<b>Total</b>	<b>164</b>	<b>126 (76.8)</b>	<b>38 (23.2)</b>	<b>1.4</b>	<b>0.3–4.9</b>	<b>108</b>	<b>55</b>	<b>1</b>

one (14.3%) lesion was non-neoplastic; oral gingivitis. The other six (85.7%) lesions were all neoplastic, with one malignant lesion, a skin soft tissue sarcoma, and five benign neoplasms. The benign neoplasms included three adenomas, a benign mast cell tumour (Fig. 7D) and a chordoma.

#### 4. Discussion

This retrospective study provides an in-depth summary of the most

common neoplastic and non-neoplastic lesions identified in exotic pet mammals in Hong Kong, drawing on 707 histopathological reports collected between 2019 and 2024 from eight different species including: rabbits, hamsters, hedgehogs, guinea pigs, chinchillas, rats, mice and ferrets, with varying distributions of lesion types and affected organ systems.



**Fig. 4.** Frequent histopathological lesions, hamsters. (A) Mammary gland, Complex adenoma. Expanding the centre of the excised mammary tissue, compressing the normal mammary gland to the periphery, is a proliferation of cystic and dilated mammary glands and epithelial cells interspersed and separated by proliferating myoepithelial cells. HE.  $\times 40$ . (B) Skin, lymphoma. Densely cellular round cell neoplasm with cells arranged in solid sheets supported by a very scant fibrovascular stroma. HE.  $\times 400$ . (C, D) Vagina, papilloma. The vaginal mucosa is markedly proliferative and papillated with frequent erosions and ulcerations. There is also prominent intercellular oedema (arrows). HE.  $\times 40$  and  $\times 400$  respectively. (E) Salivary gland, plasma cell tumour. Dense aggregates of neoplastic cells interspersed among glandular structures. HE.  $\times 400$ . (F) Skin, demodicosis. Epidermal hyperplasia and orthokeratosis with numerous demodex mites inside hair follicles and spilling onto the skin surface (arrows). HE.  $\times 40$ .

**Table 4**

Frequency of neoplastic and non-neoplastic lesions in exotic pet hedgehog in Hong Kong (2019–2024).

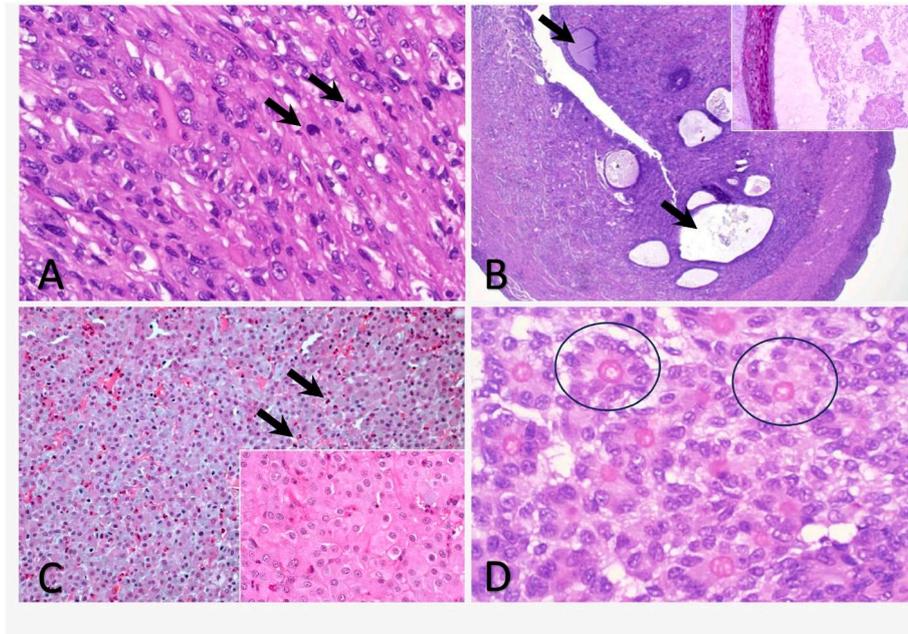
Organ system	No. (%) of lesions			Age (years)		Sex	
	All	Neoplastic	Non-neoplastic	Mean	Range	Female	Male
Reproductive tract	52 (39.7)	25 (32.9)	27 (49.1)	2.7	0.7–5.0	49	3
Skin and soft tissue	39 (29.8)	31 (40.8)	8 (14.5)	3.2	0.2–5.6	18	21
Gastrointestinal tract	24 (18.3)	6 (7.9)	18 (32.7)	2.9	1.6–4.3	18	6
Mammary gland	12 (9.2)	10 (13.2)	2 (3.6)	3.0	2.0–5.3	12	2
Special sense	2 (1.5)	2 (2.6)	0	4.0	3.0–5.0	0	2
Musculoskeletal system	2 (1.5)	2 (2.6)	0	2.0	1.7–2.2	0	2
<b>Total</b>	<b>131</b>	<b>76 (58.0)</b>	<b>55 (42.0)</b>	<b>2.9</b>	<b>0.2–5.6</b>	<b>97</b>	<b>34</b>

#### 4.1. Rabbits

In pet rabbits, our data indicated that the majority (61.7%) of diagnosed cases were neoplastic, with a near-equal distribution between benign and malignant forms and a mean age of diagnosis at 6.6 years. These findings closely align with a retrospective study in Japan that examined 1,098 histopathological samples from 883 rabbits, of which 65.7% ( $n = 721$ ) were neoplastic and 34.3% ( $n = 377$ ) were non-neoplastic lesions [10]. The most prevalent lesion in our study was adenocarcinoma, specifically uterine adenocarcinomas, followed by mammary adenocarcinomas, consistent with reports from several

previous studies [4,10–13].

CEH ranked as the fourth most prevalent lesion overall and was the second most common diagnosis among non-neoplastic and uterine lesions. Scientific literature indicates that CEH frequently occurs in pet rabbits, often ranking either first or second among uterine disorders [11, 14,15]. In our study, the average age of rabbits diagnosed with uterine disease was 5.7 years. Bertram *et al* [11] documented an average age of 6.1 years for diagnosis of uterine adenocarcinomas and 5.2 years for CEH in rabbits. The high prevalence of both uterine adenocarcinoma and CEH has led several researchers to recommend early ovariectomy as a preventive measure in pet rabbits [16].



**Fig. 5.** Frequent histopathological lesions, hedgehogs. (A) Skin, soft tissue sarcoma. The neoplastic cell population is composed of a proliferation of irregular fascicles of neoplastic spindle cells among variable amounts of collagen. There is marked anisokaryosis with prominent nucleoli and frequent atypical mitotic figures (arrows). HE.  $\times 400$ . (B) Uterus, cystic endometrial hyperplasia. The endometrial glands are variably dilated and contain pale eosinophilic to dense basophilic secretory material occasionally admixed with cellular debris (arrows). HE.  $\times 40$  Inset is of higher magnification ( $\times 400$ ) (C) Skin, Mast cell tumour. A benign tumour consisting of solid sheets of round cells with moderate to abundant cytoplasm. Eosinophils infiltrate the neoplastic cells (arrows). HE.  $\times 100$ . Inset is of higher magnification ( $\times 600$ ) (D) Ovary, granulosa cell tumour. Pathognomonic Call-Exner bodies are encircled. HE.  $\times 400$ .

**Table 5**  
Frequency of neoplastic and non-neoplastic lesions in exotic pet guinea pigs and chinchillas in Hong Kong (2019–2024).

Species/organ system	No. (%) of lesions			Age (years)		Sex	
	All	Neoplastic	Non-neoplastic	Mean	Range	Female	Male
<b>Guinea pig</b>							
Reproductive tract	23 (35.4)	6 (14.3)	17 (73.9)	3.4	1.5–5.2	23	0
Skin and soft tissue	19 (29.3)	17 (40.5)	2 (8.7)	3.9	1.5–5.8	6	13
Mammary gland	17 (26.3)	16 (38.1)	1 (4.3)	3.4	2.0–5.1	7	10
Haematolymphoid system	1 (1.5)	1 (2.4)	0	5.0	–	1	0
Urinary system	1 (1.5)	0	1 (4.3)	0.6	–	0	1
Musculoskeletal system	1 (1.5)	1 (2.4)	0	3.0	–	0	1
Special sense	1 (1.5)	0	1 (4.3)	0.8	–	1	0
Cardiovascular	1 (1.5)	0	1 (4.3)	–	–	0	1
Endocrine	1 (1.5)	1 (2.4)	0	4.9	–	1	0
<b>Total</b>	<b>65</b>	<b>42 (64.6)</b>	<b>23 (35.4)</b>	<b>3.5</b>	<b>0.6–5.8</b>	<b>39</b>	<b>26</b>
<b>Chinchilla</b>							
Reproductive tract	12 (54.5)	1 (14.3)	11 (73.3)	9.9	4.0–16.4	12	0
Skin and soft tissue	6 (27.3)	5 (71.4)	1 (6.7)	11.9	0.7–16.5	1	5
Gastrointestinal tract	1 (4.5)	0	1 (6.7)	1.5	–	0	1
Mammary gland	1 (4.5)	0	1 (6.7)	10.0	–	1	0
Peritoneum	1 (4.5)	0	1 (6.7)	2.4	–	1	0
Musculoskeletal system	1 (4.5)	1 (14.3)	0	12.0	–	1	0
<b>Total</b>	<b>22</b>	<b>7 (31.8)</b>	<b>15 (68.2)</b>	<b>9.8</b>	<b>0.7–16.5</b>	<b>16</b>	<b>6</b>

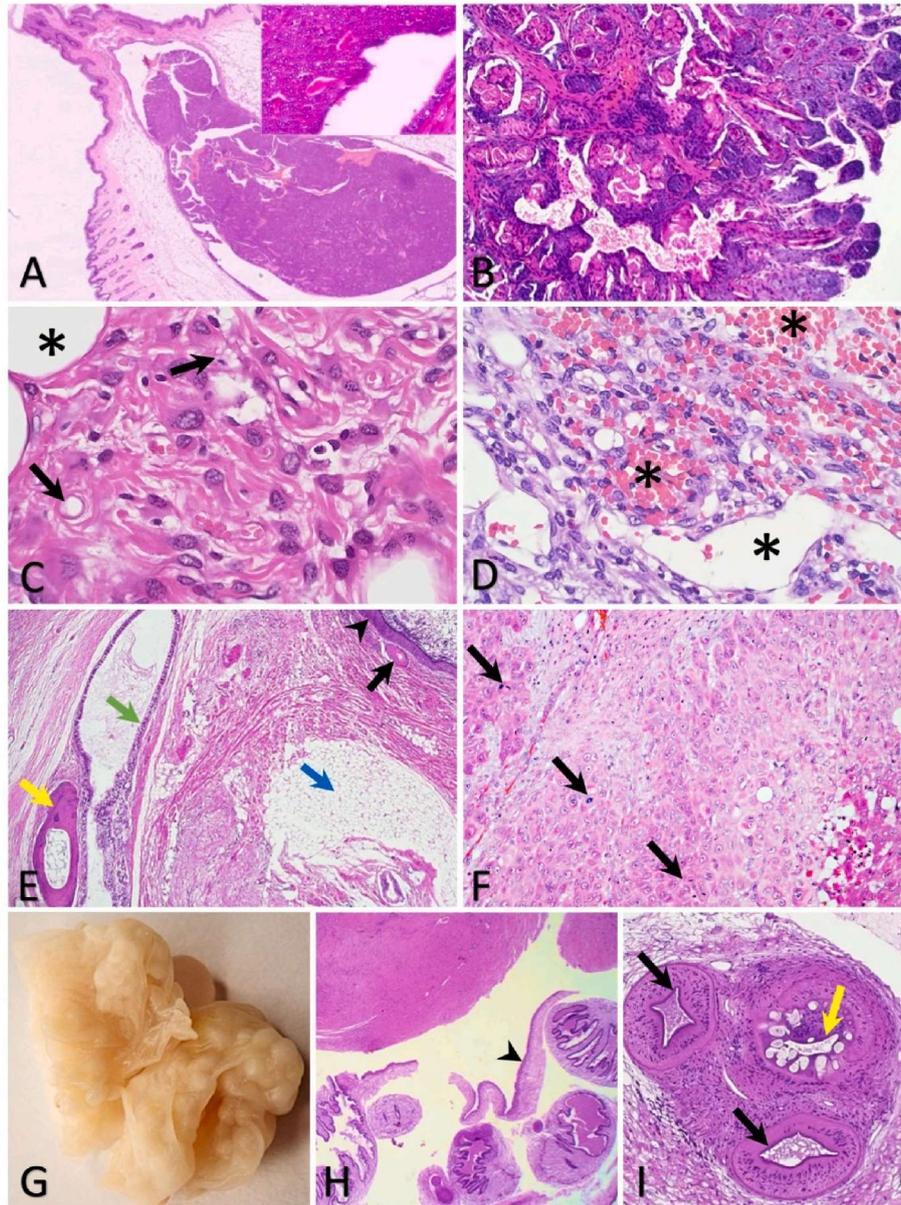
The distribution of lesions in our cohort of rabbit biopsy specimens showed a predominance in the skin and soft tissues, followed by the reproductive tract and gastrointestinal tract, a pattern that has been corroborated by other investigators [17–19]. However, it should be acknowledged that the ranking of lesion distribution among organ systems varied across studies, often depending on whether the mammary gland was classified as skin and soft tissue or treated as a distinct anatomical entity.

Trichoblastoma was the second most frequently diagnosed lesion in pet rabbits and the most commonly identified cutaneous neoplasm, which is consistent with findings from previous studies [5,17,18,20–23]. Dermatitis emerged as the most common non-neoplastic cutaneous

lesion in rabbits in the current study. Notably, pododermatitis was described as the most common skin disease in a retrospective study of 334 dermatology cases seen at the University of California at Davis, USA (1984 to 2004) [24], with lop-eared rabbits being overrepresented. In our cohort however, dermatitis was mostly recorded on the facial skin. Interestingly, at least one third of the diagnosed dermatitis cases (five out of 15) were in lop-eared rabbits, with breed being undetermined in six specimens.

#### 4.2. Hamsters

Our collection of 164 histopathological specimens from pet hamsters



**Fig. 6.** Frequent pathologic lesions, guinea pigs and chinchillas. (A) Mammary gland, guinea pig, Intraductal adenoma. Expanding and displacing the normal tissue subjacent to the nipple is a well-circumscribed, oval to irregular ectatic ductal structure containing proliferative tubular, papillary and arborized mammary epithelial structures supported by thin fibrovascular cores. HE.  $\times 40$ . Inset is of higher magnification ( $\times 400$ ) (B) Skin, guinea pig, trichofolliculoma. Multiple well-differentiated follicular structures radiating from larger central follicles, filled with lamellated keratin. HE.  $\times 40$ . (C) Skin, guinea pig, liposarcoma. Pleomorphic neoplastic cells with marked anisokaryosis and occasional intracytoplasmic, clear, sharply well-circumscribed vacuoles (arrows) are seen among adipocytes (asterisk). HE.  $\times 400$ . (D) Spleen, guinea pig, haemangiosarcoma. Proliferation of polygonal to spindle cells arranged in indistinct streams and solid sheets forming variably sized blood-filled vascular channels (asterisk). HE.  $\times 400$ . (E) Skin, chinchilla, teratoma. The neoplasm is composed of haphazardly arranged mature embryonic tissues including epidermis (arrowhead), hair follicle (black arrow), bone (yellow arrow), adipose tissue (blue arrow) and ciliated epithelium (green arrow). HE.  $\times 40$ . (F) Skin, chinchilla, squamous cell carcinoma. Mitotic figures are common (arrows). HE.  $\times 400$ . (G, H, I) Peritoneum, chinchilla, parasitic cyst. Grossly, a large piece of tissue has multiple 3-4 mm raised white nodules within it. On histology the parasitic cyst is confirmed as a cestode parasite with suckers (black arrows) and rostellum and hooks (yellow arrows) in the mouthparts consistent with the cysticercosis stage of a Taeniid species. There is an outer cuticle (arrowhead). HE.  $\times 40$ .

showed a predominance of neoplastic lesions, with an approximately equal distribution between benign and malignant forms. Biopsies were nearly twice as frequent in females than in males (female-to-male ratio: 1.96:1), which likely attributed to the high frequency of mammary glandular tumours, reproductive papillomas and pyometra observed in female hamsters. Similar to findings in rabbits, the skin and soft tissues were the most commonly affected organ systems, followed by the reproductive tract and mammary gland, further solidifying the importance of skin and reproductive health in these species. Adenomas were the most prevalent lesion, particularly those of the mammary gland,

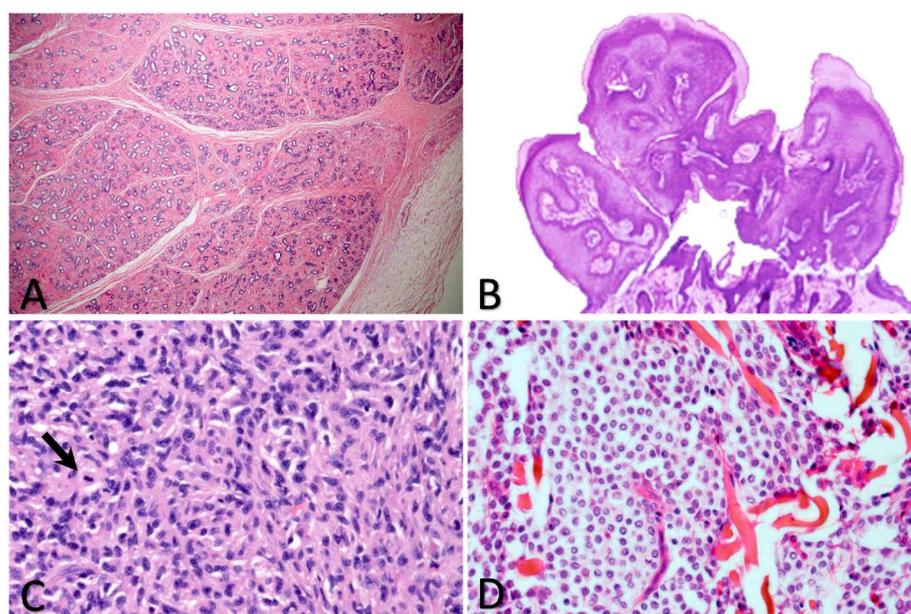
with lymphomas showing an incidence almost comparable to that of mammary adenomas.

The distribution of lesions across organ systems in our cohort aligns with previously published studies. A retrospective study from Germany that analysed 177 tumours in pet hamsters found a predominance of integumentary tumours (62% of all tumours), most of which were epithelial in origin, with the haematopoietic system being the second most commonly affected [25]. Similarly, a Taiwanese study that examined 50 masses from pet hamsters reported the skin as the most affected system, followed by the reproductive system, with malignant

**Table 6**

Frequency of neoplastic and non-neoplastic lesions in exotic pet rats, mice and ferrets in Hong Kong (2019–2024).

Species/organ system	No. (%) of lesions			Age (years)		Sex	
	All	Neoplastic	Non-neoplastic	Mean	Range	Female	Male
<b>Rat</b>							
Skin and soft tissue	9 (45.0)	8 (44.4)	1 (50.0)	1.8	0.8–3.4	3	6
Mammary gland	9 (45.0)	9 (50.0)	0	1.6	1.3–2.1	7	2
Reproductive tract	2 (10.0)	1 (5.6)	1 (50.0)	1.3	1.2–1.5	1	1
<b>Total</b>	<b>20</b>	<b>18 (90.0)</b>	<b>2 (10.0)</b>	<b>1.7</b>	<b>0.8–3.4</b>	<b>11</b>	<b>9</b>
<b>Mice</b>							
Mammary gland	5 (62.5)	5 (83.3)	0	1.8	0.1–3.8	5	0
Skin and soft tissue	2 (25.0)	1 (16.7)	1 (50.0)	4.4	3.5–5.3	0	2
Gastrointestinal tract	1 (12.5)	0	1 (50.0)	3.4	–	1	0
<b>Total</b>	<b>8</b>	<b>6 (75.0)</b>	<b>2 (25.0)</b>	<b>2.6</b>	<b>0.1–5.3</b>	<b>6</b>	<b>2</b>
<b>Ferret</b>							
Skin and soft tissue	4 (57.1)	4 (66.6)	0	4.8	4.0–6.1	1	3
Gastrointestinal tract	1 (14.3)	0	1 (100)	3.4	–	1	0
Musculoskeletal system	1 (14.3)	1 (16.7)	0	6.1	–	1	0
Special sense	1 (14.3)	1 (16.7)	0	7.1	–	1	0
<b>Total</b>	<b>7</b>	<b>6 (85.7)</b>	<b>1 (14.3)</b>	<b>5.1</b>	<b>3.4–7.1</b>	<b>4</b>	<b>3</b>



**Fig. 7.** Frequent histopathological lesions, rats, mice and ferrets. (A) Mammary gland, rat, fibroadenoma. The tumour is composed of proliferating, well-differentiated ductal and lobular structures separated by dense fibrous connective tissue. HE.  $\times 40$ . (B) Skin, rat, papilloma. Exophytic papillary projections of well-differentiated stratified squamous epithelium supported by fibrovascular stroma. HE.  $\times 40$ . (C) Mammary gland, mouse, sarcoma. Pleomorphic neoplastic cells with marked anisokaryosis and frequent mitosis (arrow). HE.  $\times 400$ . (D) Skin, ferret, mast cell tumour. Neoplastic cells are round forming cords, clusters and sheets on a pre-existing fibrovascular stroma. HE.  $\times 400$ .

mammary tumours representing the most prevalent diagnosis, in contrast to our findings, which revealed a predominance of benign mammary tumours [26]. This trend toward higher malignancy in mammary tumours was also recorded in a smaller study from Poland that evaluated 11 tumour and tumour-like lesions of the mammary gland and reproductive tract of hamsters, where malignant tumours were more prevalent [27]. In a larger study from Japan involving 90 tumours from domestic hamsters, skin tumours were the most prevalent in Djungarian hamsters, while haematopoietic tumours were the most prevalent in Syrian hamsters [28]. Notably, when stratified by species, the study reported a higher incidence of mammary adenomas than adenocarcinomas in Djungarian hamsters, while only mammary adenocarcinomas were observed in Syrian hamsters [28]. Nevertheless, when both species were considered collectively, the overall incidence of benign and malignant glandular mammary tumours were nearly equal.

A particular relevant finding from the Japanese study was the high incidence of papilloma in pet hamsters, which supports our own findings

in which papilloma ranked as the third most commonly diagnosed lesion. However, the localization differed; while the Japanese study reported a predilection for the skin of the head region, our findings showed a predilection for the lower reproductive tract, specifically the vagina of female hamsters. This observation aligns with earlier reports of spontaneous squamous cell papilloma in the vaginal mucosa of female laboratory Syrian hamsters used as control animals for 24-month experimental studies [29].

Hamster polyomavirus infection has been associated with the development of trichoepitheliomas and lymphomas in Syrian hamsters [30]. In our study, most lymphomas were cutaneous in origin, consistent with findings from previous studies [25,28,31,32]. However, additional lymphoma cases were identified in the lymph nodes and testicles, which have also been previously documented in pet hamsters [25,33]. Another noteworthy observation in our hamster data was the identification of five plasma cell tumours, two of which were localized in the salivary gland. Other reports [34,35] of extramedullary plasma cell tumours in

the salivary glands of Syrian hamsters imply a propensity for this tumour to develop in the salivary glands of hamsters. Trichoepithelioma was detected in three biopsies specimens. However, no further analysis was conducted in our study to explore a potential correlation between hamster polyomavirus and the diagnosed lymphomas or trichoepitheliomas.

Among non-neoplastic lesions diagnosed, dermatitis and pyometra were equally prevalent, highlighting common inflammatory and reproductive issues in hamsters. While pyometra has been described in pet hamsters [36,37], comprehensive data regarding its prevalence remains scarce. Demodicosis was diagnosed in two instances. Hamsters are known to be more susceptible to demodicosis than other companion rodents [32].

#### 4.3. Hedgehogs

Hedgehogs had a slightly lower, but still substantial, proportion of neoplastic lesions (58%), with malignant neoplasms being more prevalent than benign ones. This observation aligns with findings from two retrospective studies conducted in the United States [23] and Japan [38], both of which reported a predominance of malignant neoplastic lesions in hedgehogs. In our cohort, the most commonly submitted tissues with pathological lesions originated from the reproductive organs, followed by the skin and soft tissues, gastrointestinal tract and mammary gland. Raymond and Garner [23] identified the integumentary system as the most frequently affected tissue in hedgehogs with spontaneous tumours, followed by the haemolymphatic, digestive and endocrine systems. In our study, the most commonly identified lesion was sarcoma of uncertain differentiation, often cutaneous or uterine, which suggests a high propensity for aggressive mesenchymal tumours in hedgehogs. Other sarcomas identified were two leiomyosarcoma, two fibrosarcomas, two cutaneous histiocytic sarcomas, one cutaneous myxosarcoma and one cutaneous haemangiosarcoma. These findings are in line with a study by Shiga *et al* [10] on four-toed hedgehogs in Japan, where soft tissue sarcomas were the most frequently diagnosed lesion of the integumentary system. Furthermore, gingivitis was the most frequently diagnosed lesion in the digestive system and CEH in the reproductive system. This is in line with our findings, where sarcomas were the most identified lesion, most of which were cutaneous and uterine. The consistency of these patterns across geographically and demographically diverse cohorts underscores the frequent occurrence of sarcomas in hedgehogs.

The second most identified lesion and the most frequently diagnosed in the reproductive tract was CEH, further emphasizing reproductive health concerns in female hedgehogs. Of the 24 lesions biopsied from the digestive system, gingivitis accounted for 16 cases, making it the third most common lesion identified. This finding aligns with prior literature that documented tooth and gum diseases as frequent afflictions in pet hedgehogs [39]. While oral squamous cell carcinoma has been reported as the most common neoplasm in some studies [40], our dataset revealed only two cases as oral squamous cell carcinomas among the 24 digestive system specimens. This disparity may result from variations in sample size and husbandry. In this study, half of the mammary gland tumours were adenocarcinomas, supporting other reports where most of hedgehog mammary tumours were adenocarcinomas [27,38,41]. Additionally, mast cell tumours represented 5.3% of all diagnosed lesions, with the majority being cutaneous. Although, sporadic case reports of mast cell tumours in hedgehogs have been documented [42,43], the true prevalence is uncertain. Unlike in canine and feline medicine, a universally validated, two- or three-tiered histopathological grading system such as the Kiupel or Patnaik systems for cutaneous mast cell tumours (MCTs) in hedgehogs has not yet been established. Our classification of MCTs into benign and malignant lesions here was based on degree of cellular differentiation and atypia, growth pattern and mitotic count. A key study examining cutaneous MCTs in African four-toed hedgehogs [44] categorized MCTs into two main groups with distinct

prognostic implications, which serves as the current best practice for histopathological differentiation. The distinction is primarily based on the degree of cellular differentiation and atypia, which correlates with clinical behaviour. The two categories identified are well-differentiated MCT, associated with a benign course, and atypical MCT, associated with a more aggressive and malignant course. More prospective studies of MCTs with case follow-up in hedgehogs are warranted to better characterize tumour behaviour and clinical outcomes in this species.

#### 4.4. Guinea pigs

The study analysed 65 histopathological specimens from 64 guinea pigs, with a mean age of 3.5 years, and recorded a predominance of neoplastic lesions, accounting for 64.6% of cases, most of which were benign in nature. The reproductive system was the most frequently affected organ system (35.4%), followed by the skin and soft tissues (29.2%) and the mammary gland (26.2%). The most common diagnosis included CEH, followed by mammary adenomas, trichofolliculoma and lipoma. A comparable mean age was reported by Otrocka-Domagala *et al* [5], who reported an average age of around 3.5 years in a study focusing exclusively on skin and subcutaneous tissues and excluding mammary tumours. This similarity suggests that this age group might be particularly susceptible to developing various pathologies, or may reflect the typical age at which guinea pigs are most often presented for veterinary examination. Notable overlap between the findings by Otrocka-Domagala *et al* [5] and our findings include the predominance of benign tumours and the frequent identification of lipoma and trichofolliculoma in guinea pigs. This consistency reinforces the understanding that while lumps and bumps are common in guinea pigs, a significant proportion are not malignant.

Further support comes from a UK-based retrospective study analysing 619 biopsy samples of externally palpable masses submitted from pet guinea pigs, which also reported a high prevalence of benign tumours, with lipoma being the most frequently diagnosed neoplasm, while trichofolliculoma succeeds it in prevalence [3]. While this UK study expanded its scope beyond cutaneous and subcutaneous tumours to include all palpable mammary, thyroid and salivary gland masses, it did not encompass internal organ lesions, such as reproductive tract pathologies. In contrast, our study, by including biopsies from all organ systems, revealed a high prevalence of reproductive lesions, including CEH and leiomyoma, which would not have been captured by the UK study's methodology.

In contrast to several previous reports that identified mammary carcinomas as the predominant neoplasm in guinea pigs, our findings showed a higher occurrence of benign mammary tumours. This discrepancy could not be attributed to age in our study, but smaller sample size may factor into this variation [3,26,27]. Moreover, our findings corroborate observations from those studies indicating that male guinea pigs are unusually highly susceptible to mammary tumours. In our data, seven out of the nine mammary adenomas and two out of the three mammary lipomas occurred in male guinea pigs, supporting emerging evidence of sex-related susceptibility to mammary gland neoplasia in this species. This aligns with recent findings demonstrating a male predisposition to ductal-associated and malignant mammary tumours [45]. However, whereas benign mammary neoplasms predominated in males in our cohort, malignant lesions were most common in the cohort reported by Schöniger *et al* [45].

Although less frequent than benign lesions, the detection of malignant soft tissue sarcomas including liposarcoma, fibrosarcoma and haemangiosarcoma is in line with previous studies [3,5,46] and underscores the importance of histopathological diagnosis for any suspicious mass. An additional notable finding was the relatively frequent diagnosis of cystic rete ovarii, ranking as the 7th most commonly identified lesion in our cohort. Previous studies have highlighted the high prevalence of ovarian cysts in guinea pigs, predominantly arising from the rete ovarii and often linked to uterine conditions such as CEH

[47,48]. These findings have led many clinicians and researchers to advocate ovariohysterectomy as a preventative or therapeutic intervention in affected individuals [47,48].

#### 4.5. Chinchilla

In contrast to most exotic mammalian pets, chinchillas in our study had a higher prevalence of non-neoplastic lesions (68.2%) compared to neoplastic ones. A particularly noteworthy finding was the high frequency of reproductive system lesions (54.5%), with endometritis and CEH each accounting for 18.2% of submitted cases. This finding is consistent with existing literature on chinchilla pathology, which reported that female reproductive tract diseases, especially endometritis and pyometra, are common in pet chinchillas, particularly in older intact females [49,50]. The identification of two pyometra cases in our study further supports this trend. These findings highlight the importance of early diagnosis and intervention, and support the prophylactic spaying of non-breeding females to mitigate reproductive morbidity.

Neoplastic lesions represented 31.8% of the identified lesions in this study, with both benign and malignant forms identified. A diverse range of tumour types was identified, including cutaneous lymphoma, uterine leiomyosarcoma, cutaneous teratoma and osteoma, contradicting some literature suggesting that neoplasia is rare in chinchillas despite their relatively long lifespan [50]. Notably, we identified three cases of squamous cell carcinoma, corroborating recent case reports that highlight the occurrence of this malignancy in pet chinchillas [51]. Moreover, the diagnosis of peritoneal cysticercosis in our cohort underscores the relevance of parasitic infections in pet chinchillas. This finding suggests possible environmental contamination with *Taenia* spp eggs, raising concerns about husbandry practices and the biosecurity of chinchilla environments, especially with respect to dietary sources and exposure risks.

#### 4.6. Rats, mice and ferrets

Tissue biopsies submitted from rats, mice and ferrets in Hong Kong were considerably lower in number compared to those from other exotic pet mammals. This disparity is likely influenced by the lower perceived economic value of these species, where diagnostic costs can outweigh the animal's initial purchase value. As a result, owners may opt for palliative care or even euthanasia rather than pursue advanced diagnostics like histopathology, especially in rats and mice. Also, an additional and significant factor in the case of ferrets is the legal restriction on their importation into Hong Kong [52]. As a result, ferrets are extremely uncommon in Hong Kong, which directly limits both their ownership and the subsequent submission of clinical samples for diagnostic testing.

Despite the limited sample size, our study revealed a high proportion of neoplastic lesions among submitted specimens: 90% in rats, 75% in mice and 85.7% in ferrets. Benign tumours dominated the neoplastic lesions in both rats and ferrets. In rats, fibroadenoma, particularly mammary fibroadenomas, were overwhelmingly common, corroborating findings from previous studies [26,27,31,53,54].

Among mice, mammary gland tumours were the most frequently submitted biopsies, followed by cutaneous lesions. In a retrospective study by Paździor-Czapula *et al* [27] focusing on mammary and reproductive tract tumours and tumour-like lesions in small pet mammals in Poland, mammary carcinomas were the only lesions recorded, supporting our finding of a high prevalence of mammary gland adenocarcinomas in mice. The development of mammary tumours in mice can be attributed to infection by the mouse mammary tumour virus [26]; however, no further diagnostic investigation was done in our study to confirm or refute this probability.

In ferrets, mast cell tumours are among the most commonly diagnosed neoplasms [22]. In our dataset, however, the number of submitted ferret biopsies was limited to seven specimens, each yielding a distinct

diagnosis. This limited sample size restricts our ability to draw meaningful conclusions about lesion prevalence in this species.

## 5. Conclusion

The findings of this study regarding neoplastic and non-neoplastic lesions across a range of exotic pet mammal species largely align with, and build upon, existing knowledge in exotic animal pathology. Importantly, they offer novel insights into species-specific lesion prevalence within the unique context of Hong Kong's exotic pet population. The data underscore the critical role of histopathological evaluation in the diagnosis and management of diseases in exotic mammals. Furthermore, the results emphasize the necessity for ongoing disease surveillance to inform diagnostic and therapeutic strategies and to enhance animal welfare for this increasingly popular group of companion animals.

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## Declaration of competing interest

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

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