Swiss Feline Cancer Registry: A Retrospective Study of the Occurrence of Tumours in Cats in Switzerland from 1965 to 2008


*Collegium Helveticum, Universität Zürich und Eidgenössische Technische Hochschule Zürich (ETHZ), †Institut für Veterinärpathologie, ‡Departement Nutztiere, †Geographisches Institut, Universität Zürich, ‡‡Institut für Verkehrspflanung und Transportsysteme, ETHZ, Zürich, ††Institut für Tierpathologie, Universität Bern, Bern, ‡‡‡Zyt-Histo Diagnostik in Rorbach Freienstein and †††Institut für Pharmazeutische Wissenschaften, ETHZ, Zürich, Switzerland

Summary
Cancer is one of the leading causes of death in companion animals. Information on the epidemiology of cancer is instrumental for veterinary practitioners in patient management; however, spontaneously arising tumours in companion animals also resemble those in man and can provide useful data in combating cancer. Veterinary cancer registries for cats are few in number and have often remained short-lived. This paper presents a retrospective study of tumours in cats in Switzerland from 1965 to 2008. Tumour diagnoses were coded according to topographical and morphological keys of the International Classification of Oncology for Humans (ICD-O-3). Correlations between breed, sex and age were then examined using a multiple logistic regression model. A total of 18,375 tumours were diagnosed in 51,322 cats. Of these, 14,759 (80.3%) tumours were malignant. Several breeds had significantly lower odds ratios for developing a tumour compared with European shorthair cats. The odds of a cat developing a tumour increased with age, up to the age of 16 years, and female cats had higher risk of developing a tumour compared with male cats. Skin (4,970; 27.05%) was the most frequent location for tumours, followed by connective tissue (3,498; 19.04%), unknown location (2,532; 13.78%) and female sexual organs (1,564; 8.51%). The most common tumour types were epithelial tumours (7,913; 43.06%), mesenchymal tumours (5,142; 27.98%) and lymphoid tumours (3,911; 21.28%).

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Introduction
Cancer is a widespread disease and is a major cause of death in man and companion animals (Dorn, 1967). Cancer registries provide data for epidemiological studies that allow for incidence calculation, risk factor identification and development of prevention and control strategies, as well as treatment and spatial evaluation. Such studies have the potential to influence the therapy of individual cancer patients (Parkin, 2006; Vascellari et al., 2009; Nødtvedt et al., 2011a). Human cancer registries were already established in the 1940s (Parkin, 2006); however, veterinary cancer registries have existed only sporadically and for short periods of time (Dobson et al., 2002; Parkin, 2006; Bronden et al., 2007; Vascellari et al., 2009). One of the earliest cancer registries for companion animals was the California Animal Neoplasm registry, which started in 1963 with the goal of identifying all tumours in animals in the...
region over a 3-year period (Dorn et al., 1968a,b). Several registries in other countries followed (Moe et al., 2001, 2008; Merlo et al., 2008; Vascellari et al., 2009; Brønden et al., 2010; Nødtvedt et al., 2011b). Due to termination of many animal registries, as well as lack of communication and collaboration between the different registries, their potential as information sources has not been fully exploited and this renders them largely underused (Brønden et al., 2007).

Registry continuation, together with collaboration among registries, increases the size of the database, allowing the evaluation of temporary trends, fluctuations in cancer occurrence and appraisal of potential environmental and individual risk factors. Risk factors for specific cancers such as age, breed, gender and neuter status can be assessed and are a valuable source of information for veterinary practitioners (Dorn, 1967; Vascellari et al., 2009; Brønden et al., 2010). For most neoplastic diseases in animals, there are no standard treatments, which allows some latitude in prospective clinical trials. New therapeutic agents could be tested on pets with potential benefits for both man and animals (Vail and MacEwen, 2000; Paoloni and Khanna, 2008).

Current animal models for studying cancer consist of rodents with chemically- or virally-induced tumours. These models have many limitations and fail to reflect many aspects of naturally occurring human cancer (Hewitt, 1978; Hansen and Khanna, 2004). Companion animals with spontaneously developing tumours are more analogous to human cancer cases (Dorn, 1967; Priester, 1977; MacEwen, 1990; Vail and Thamm, 2004; Rowell et al., 2011). One reason is that these animals share the same environment with their owners and therefore are exposed to similar risk factors. Furthermore, there are striking histopathological, anatomical, genetic and biomolecular similarities between feline, canine and human tumours (Calabrese, 1986; Porrello et al., 2004, 2006; Withrow et al., 2013). A computerized database for companion animal tumours with a coding system corresponding to human cancer registry coding is therefore desirable (Monsein, 1991; Folk, 2004).

Feline tumours have not been investigated extensively in the past and studies on the feline population have mostly been performed with very sparse data (Withrow et al., 2013). To our knowledge, there is no feline cancer registry that has existed for a significant period of time and has allowed decent data collection.

The aim of the present retrospective study was to prepare and analyse cat patient records from all over Switzerland, which had been stored for the past 40 years. By this means, a feline cancer registry was created that can be continued over subsequent years and used to answer epidemiological questions and investigate similarities between feline and human cancers.

Materials and Methods

Data Source

For this retrospective study, feline patient records were gathered from three veterinary diagnostic laboratories in Switzerland: the Vetsuisse faculty’s Institute for Veterinary Pathology, Zürich (IVPZ), the Institut für Tierpathologie, Bern (ITP) and a private veterinary diagnostic laboratory (Zyto-Histodiagnostik in Rorbas Freienstein, Switzerland).

The records retrieved from IVPZ-SLK (1965–1988) were patient records \( n = 10,799 \) from feline post-mortem and biopsy samples analysed by histopathology. Diagnoses were recorded on punch cards using diagnostic key words (Keydex\textsuperscript{®}, Fa. Royal McBee; Stünzi and Lott-Stolz, 1967). An external company (Scydoc\textsuperscript{®}, Zug, Switzerland) performed the digitalization of the punch cards and results were cross-checked and completed using the original typed reports.

The records retrieved from the IVPZ-APPX (1987–2008) were patient records \( n = 26,844 \) from feline biopsy, cytology and post-mortem examinations (analysed by histopathology) and were available from the electronic patient record system at IVPZ (www.APPX.com).

The records retrieved from the ITP-Berne (1983–2008) were digitized patient records \( n = 12,028 \) from feline biopsy and post-mortem examinations, analysed by histopathology.

The records retrieved from Zyto-Histodiagnostik (2007–2008) were digitized patient records \( n = 1,651 \) based on samples of biopsy histopathology.

Data Preparation and Modification

Data from the different sources were merged and standardized on the basis of breed, age, gender and neuter status, place of origin (canton), year and method of examination.

Tumour diagnoses were coded according to topographical and morphological keys of the International Classification of Oncology for Humans (ICD-O-3). Cysts were not counted as tumours. Both benign and malignant tumours were included.

The 18 most frequent feline breeds with at least 90 individuals were registered; the remaining breeds were classified as ‘other breeds’. In a number of
patient records the breed was not recorded in the original database and for these cases breed was classified as ‘unknown’. In other patient records the breed was only recorded for purebred cats and not for European shorthair cats. The latter were grouped as ‘unknown’; although it can be assumed that most of them were in fact European shorthair cats. In the early records, European shorthair cats were called ‘house cats’. These were amalgamated under the term ‘European shorthair cats’.

The sex of the animals was recorded as one of: male, male neutered, female, female neutered and unknown.

The origins of the samples were unevenly distributed over Switzerland, with most of the samples deriving from the canton of Zurich. The canton as a variable was therefore integrated as a confounding factor. The year of submission was also integrated as a confounding factor because over time histological examinations have become more common and the number of submissions had increased accordingly. Another variable included was the method of examination due to different purposes of analysis. While biopsy and cytology samples were used for directed tumour cell searches, post-mortem examinations often uncovered the presence of a tumour.

To unify anatomical locations where the same was meant, two specifications were changed: leucosis with the location ‘bone marrow’ was changed to the location ‘unknown’ and fibrosarcomas with the location ‘skin’ were changed to the location ‘soft tissue’ (i.e. subcutis).

Statistical Evaluation

The feline cancer registry is patient-based since there are only estimates of the cat population in Switzerland. Data editing and all statistical analyses were performed using Stata Software (StataCorp., 2011; Stata Statistical Software: Release 12; College Station, Texas, USA). Analyses were carried out using Chi-Square/Fisher’s exact test. Significant variables were further integrated and analysed in a multiple logistic regression model (using binary logistic models and stepwise backward procedure). The following variables were included in the final model as fixed terms: canton of origin, age, sex/neuter status, breed, year and method of examination. \( P \leq 0.05 \) was considered significant and odds ratios (ORs) with 95% confidence intervals (CI) were calculated.

Results

Dataset

The dataset consisted of a total of 51,322 cats that underwent pathological examination. The number of patients with confirmed tumours was 17,856 (34.79%). Of these, 483 cats (2.7%) had multiple primary tumours, adding up to a total of 18,375 diagnosed tumour lesions. Of these, 14,759 (80.92 %) were malignant. The number of post-mortem examinations (Fig. 1) remained roughly the same from 1965 to 2008, but the number of biopsy submissions (Fig. 2) and cytological examinations (Fig. 3) steadily increased after 1995. The average proportion of cats with tumours diagnosed by post-mortem examination was 16.56% (3,202/19,340); for biopsy samples this was 50.9% (11,828/23,236) and for cytology specimens 32.3% (2,825/8,746).

Breed Distribution

The numbers of cats belonging to a given breed varied. Most cats were European shorthairs. In the statistical evaluation, this breed was used as the standard against which all other breeds were compared. Table 1 lists the distribution of cat breeds as well as their tumour frequency and the proportion of malignant tumours. European shorthair cats 24,023/51,322 (46.81%) accounted for almost half of the patients. Many patient records (17,861/51,322; 34.8%) lacked a breed annotation. Tumour frequency varied from 15.93% (54/339) in Birman cats to 40.94% (9,834/24,023) in European shorthair cats. The frequency of malignant tumours also differed between breeds and ranged from 62.16% (23/36, Burmese) to 94.44% (16/17, Devon rex).

Using multiple regression analysis including all confounding factors, the odds for a single cat breed of developing a tumour were compared with those of the European shorthair cat (OR = 1) (Fig. 4).

No other breed had significantly higher odds of
developing a tumour than the European shorthair cat; however, several breeds had significantly lower ORs (Fig. 4).

For malignant tumours only, the picture did not change substantially. There were only two breeds that showed significant changes compared with the overall tumour count. Chartreux cats had significantly lower odds of developing malignant tumours compared with the European shorthair cat ($P < 0.05, OR = 0.74 [CI = 0.57; 0.97]$), while the OR of Devon rex cats did not differ significantly from that of European shorthair cats ($P = 0.15, OR = 0.64 [CI = 0.35; 1.17]$).

Sex Distribution

Of the 51,322 cats recorded, the majority were neutered males ($n = 15,652$) followed by neutered females ($n = 12,388$), entire females ($n = 10,828$) and entire males ($n = 9,396$). In some specimens ($n = 3,058$) the sex of the cat was not specified.

Tumours occurred most frequently in neutered female cats (43.63%, 5,405/12,388), followed by neutered males (36.62%, 5,731/15,652), entire females (32.43%, 3,512/10,828) and entire males (25.78%, 2,422/9,396). If, however, all confounding factors (age, sex/neuter status, breed, year and method of examination and canton of origin) were taken into account, the picture looked very different: the odds of a neutered male cat developing a tumour were significantly lower compared with those of entire males ($P < 0.01, OR = 0.88 [CI = 0.82; 0.94]$). Similarly, the odds of a neutered female cat developing a tumour were significantly lower than those of an entire female ($P < 0.01, OR = 0.85 [CI = 0.80; 0.91]$). For tumours generally, the odds of a female cat developing a tumour compared with those of a male cat were significantly higher ($P < 0.01, OR = 1.18 [CI = 1.14; 1.24]$).

However, when only malignant tumours were considered, the neutered male versus entire male ($P < 0.01, OR = 0.88 [CI = 0.82; 0.94]$) and the female versus male ($P < 0.01, OR = 1.20 [CI = 1.15; 1.26]$) ORs were similar to those where all tumours were considered. The ORs of neutered female cats versus entire female cats did not differ significantly ($P = 0.07, OR = 0.94 [CI = 0.88; 1.00]$).

The sex distribution of the cats varied depending on the method of diagnosis (i.e. post-mortem, biopsy or cytology). For post-mortem samples the likelihood of entire cats having a tumour was higher compared with that of neutered cats; in biopsy specimens the reverse was the case. In cytology specimens, no clear trend was discerned. In all examination methods female cats had higher odds of developing a tumour than did male cats (Fig. 5).

Age Distribution

The highest number of samples per age group expressed in years were from cats <1 year of age. Very few samples were from cats >20 years of age and these were assembled in one group: ‘age >20’.

The odds of a cat developing a tumour increased with age, peaked at 16 years of age and then decreased slightly (cats age <1 = set as standard, OR = 1). Malignant tumours arose more frequently in older cats (Figs. 6 and 7).

Multiple Tumours

Relatively few cats ($n = 485$) had more than one primary tumour. Of all patients with a tumour diagnosis
(n = 17,856), they represented only 2.7%. There were no differences between cats of different sexes. The only breed that differed significantly from European shorthair cats was the Siamese, which had a much lower multiple tumour rate ($P < 0.02$, OR = 0.36 [0.16–0.83]). Most diagnoses of several primary tumours derived from post-mortem examinations.

Table 1: Occurrence of tumours and their relationship to breed

<table>
<thead>
<tr>
<th>Breed</th>
<th>Sample size (n)</th>
<th>Proportion of all cats (%)</th>
<th>Cats with a tumour (n)</th>
<th>Proportion of cats with a tumour (%)</th>
<th>Proportion of malignant tumours (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>European shorthair</td>
<td>24,025</td>
<td>46.81</td>
<td>9,834</td>
<td>40.94</td>
<td>80.88</td>
</tr>
<tr>
<td>Unknown</td>
<td>17,861</td>
<td>34.80</td>
<td>5,553</td>
<td>31.09</td>
<td>81.55</td>
</tr>
<tr>
<td>Persian</td>
<td>3,532</td>
<td>6.88</td>
<td>914</td>
<td>25.88</td>
<td>71.73</td>
</tr>
<tr>
<td>Siamese</td>
<td>1,954</td>
<td>3.81</td>
<td>641</td>
<td>32.80</td>
<td>80.83</td>
</tr>
<tr>
<td>Maine Coon</td>
<td>704</td>
<td>1.37</td>
<td>144</td>
<td>20.45</td>
<td>71.72</td>
</tr>
<tr>
<td>Abyssinian</td>
<td>380</td>
<td>0.74</td>
<td>83</td>
<td>21.84</td>
<td>79.07</td>
</tr>
<tr>
<td>Other breeds</td>
<td>346</td>
<td>0.67</td>
<td>73</td>
<td>21.10</td>
<td>80.26</td>
</tr>
<tr>
<td>British shorthair</td>
<td>345</td>
<td>0.67</td>
<td>63</td>
<td>18.37</td>
<td>65.63</td>
</tr>
<tr>
<td>Birman</td>
<td>339</td>
<td>0.66</td>
<td>54</td>
<td>15.93</td>
<td>77.78</td>
</tr>
<tr>
<td>Chartreux</td>
<td>337</td>
<td>0.66</td>
<td>116</td>
<td>34.42</td>
<td>72.73</td>
</tr>
<tr>
<td>Norwegian forest</td>
<td>315</td>
<td>0.61</td>
<td>71</td>
<td>22.68</td>
<td>69.33</td>
</tr>
<tr>
<td>Domestic longhair</td>
<td>282</td>
<td>0.55</td>
<td>80</td>
<td>28.37</td>
<td>77.11</td>
</tr>
<tr>
<td>Burmese</td>
<td>182</td>
<td>0.35</td>
<td>36</td>
<td>19.78</td>
<td>63.88</td>
</tr>
<tr>
<td>Turkish Angora</td>
<td>175</td>
<td>0.34</td>
<td>36</td>
<td>33.14</td>
<td>75.00</td>
</tr>
<tr>
<td>Mixed breed</td>
<td>143</td>
<td>0.28</td>
<td>31</td>
<td>21.68</td>
<td>84.38</td>
</tr>
<tr>
<td>Oriental shorthair</td>
<td>115</td>
<td>0.22</td>
<td>34</td>
<td>29.57</td>
<td>88.24</td>
</tr>
<tr>
<td>Ragdoll</td>
<td>105</td>
<td>0.20</td>
<td>22</td>
<td>20.95</td>
<td>72.73</td>
</tr>
<tr>
<td>Somali</td>
<td>98</td>
<td>0.19</td>
<td>32</td>
<td>32.65</td>
<td>81.82</td>
</tr>
<tr>
<td>Devon Rex</td>
<td>90</td>
<td>0.18</td>
<td>17</td>
<td>18.89</td>
<td>94.12</td>
</tr>
</tbody>
</table>

Fig. 4. Odds ratios (ORs) and 95% confidence intervals (CIs) for tumour diagnoses for the most common cat breeds compared with the European shorthair cat (OR = 1). Unknown breed ($P = 0.4$, OR = 0.98 [CI = 0.92; 1.03]), Persian ($P < 0.01$, OR = 0.59 [CI = 0.54; 0.65]), Siamese ($P < 0.01$, OR = 0.84 [CI = 0.75; 0.94]), Maine Coon ($P < 0.01$, OR = 0.73 [CI = 0.59; 0.9]), Abyssinian ($P < 0.01$, OR = 0.58 [CI = 0.44; 0.77]), Other breeds ($P < 0.01$, OR = 0.66 [CI = 0.49; 0.89]), British shorthair ($P < 0.01$, OR = 0.66 [CI = 0.49; 0.9]), Birman ($P < 0.01$, OR = 0.38 [CI = 0.28; 0.53]), Chartreux ($P = 0.32$, OR = 0.88 [CI = 0.68; 1.13]), Norwegian forest ($P < 0.05$, OR = 0.73 [CI = 0.54; 0.99]), Domestic longhair ($P < 0.01$, OR = 0.58 [CI = 0.43; 0.78]), Burmese ($P < 0.01$, OR = 0.52 [CI = 0.34; 0.78]), Turkish Angora ($P = 0.72$, OR = 0.94 [CI = 0.65; 1.33]), Mixed breed ($P = 0.77$, OR = 0.93 [CI = 0.59; 1.48]), Oriental shorthair ($P = 0.39$, OR = 1.24 [CI = 0.76; 2.02]), Ragdoll ($P = 0.1$, OR = 0.64 [CI = 0.38; 1.08]), Somali ($P = 0.69$, OR = 1.11 [CI = 0.68; 1.81]), Devon Rex ($P < 0.05$, OR = 0.46 [CI = 0.25; 0.83]).
Classification of the Most Common Tumour Types According to ICD-O-3

A summary of the most common tumour types in cats \( (n = 18,375) \) revealed that epithelial tumours (ICD-O-3: 8010–8587; 9050–9058, \( n = 7,913; \) 43.06%) were the most common, followed by mesenchymal tumours (ICD-O-3: 8680–8711; 8800–8940; 9120–9150; 9580, \( n = 5,142; \) 27.98%), lymphoid tumours (ICD-O-3: 9590–9732; 9740–9755; 9800–9931; 9960, \( n = 3,911; \) 21.28%), unclassified tumours (ICD-O-3: 8000, \( n = 476; \) 2.59%), melanoma (ICD-O-3: 8720–8730, \( n = 349; \) 1.9%), skeletal tumours (ICD-O-3: 9180–9262, \( n = 336; \) 1.83%) and neural neoplasia (ICD-O-3: 9380–9460; 9503–9522; 9530; 9540–9570, \( n = 197; \) 1.07%) (Fig. 8). The frequency of these tumour types for each examination method is shown in Table 2.
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Table 2
Frequency of tumour types (>1%) for post-mortem, biopsy and cytology samples

<table>
<thead>
<tr>
<th>Tumour type</th>
<th>Post-mortem</th>
<th>Biopsy samples</th>
<th>Cytology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>tumour count</td>
<td>tumour count</td>
<td>tumour count</td>
</tr>
<tr>
<td>Epithelial tumours</td>
<td>1,281</td>
<td>5,715</td>
<td>912</td>
</tr>
<tr>
<td>Mesenchymal tumours</td>
<td>280</td>
<td>4,116</td>
<td>746</td>
</tr>
<tr>
<td>Lymphoid tumours</td>
<td>1,529</td>
<td>1,402</td>
<td>980</td>
</tr>
<tr>
<td>Unclassified tumours</td>
<td>132</td>
<td>188</td>
<td>156</td>
</tr>
<tr>
<td>Melanoma</td>
<td>12</td>
<td>303</td>
<td>34</td>
</tr>
<tr>
<td>Skeletal tumours</td>
<td>56</td>
<td>259</td>
<td>21</td>
</tr>
<tr>
<td>Neural tumours</td>
<td>123</td>
<td>72</td>
<td>2</td>
</tr>
</tbody>
</table>

Malignancy of the Most Common Tumour Types

The highest percentage of malignant neoplasms was found among skeletal tumours (318/336, 94.64%) followed by melanomas (326/349, 93.64%), lymphoid tumours (3,493/3,911, 89.34%), mesenchymal tumours (4,358/5,142, 84.75%), epithelial tumours (5,846/7,913, 73.88%) and unclassified tumours (343/476, 72.06%). A low malignancy rate (57/91, 28.93%) was seen for neural neoplasia. Number per tumour type and proportion of malignant tumours are shown in Fig. 8.

Most Common Anatomical Tumour Locations

The skin (4,970/18,375, 27.05%) was the most frequent location for tumours, followed by connective tissue (3,498, 19.04%), unknown location (2,532, 13.78%), female sexual organs (1,564, 8.51%), gastrointestinal tract (1,373, 7.47%), respiratory system (1,223, 6.66%), oral cavity/pharynx (980, 5.33%), lymph nodes (351, 1.91%), musculoskeletal system (345, 1.88%), endocrine glands (339, 1.84%), haemopoietic system (329, 1.79%), abdominal cavity (257, 1.4%) and urinary tract (232, 1.26%). The frequency of these anatomical tumour locations for each examination method is shown in Table 3.

Malignancy Rates in the Most Common Anatomical Tumour Locations

The highest percentage of malignant tumours was found among tumours in lymph nodes (343/351, 97.72%), followed by tumours of unknown location (2,419/2,332, 95.54%) and tumours in the abdominal cavity (243/257, 94.55%), the musculoskeletal system (321/345, 93.04%), the urinary system (213/232, 91.81%), the haemopoietic system (299/329, 90.88%), the oral cavity/pharynx (862/980, 87.96%), the gastrointestinal tract (243/257, 94.55%), the respiratory system (1,050/1,223, 85.85%), the connective tissue (2,981/3,498, 85.22%), the female sexual organs (1,280/1,564, 81.84%) and the skin (3,232/4,970, 65.03%). A lower malignancy rate was present in the endocrine glands (86/339, 25.37%). Number of tumours per anatomical location and the proportion of malignant tumours are shown in Fig. 9.

Table 3
Most common anatomical tumour locations (>1%) for post-mortem, biopsy and cytology samples

<table>
<thead>
<tr>
<th>Location</th>
<th>Post-mortem</th>
<th>Biopsy samples</th>
<th>Cytology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>tumour count</td>
<td>tumour count</td>
<td>tumour count</td>
</tr>
<tr>
<td>Skin</td>
<td>105</td>
<td>4,225</td>
<td>640</td>
</tr>
<tr>
<td>Connective tissue</td>
<td>109</td>
<td>2,982</td>
<td>407</td>
</tr>
<tr>
<td>Unknown location</td>
<td>1,544</td>
<td>863</td>
<td>125</td>
</tr>
<tr>
<td>Female sexual organs</td>
<td>61</td>
<td>1,451</td>
<td>32</td>
</tr>
<tr>
<td>Gastrointestinal tract</td>
<td>469</td>
<td>370</td>
<td>334</td>
</tr>
<tr>
<td>Respiratory tract</td>
<td>511</td>
<td>326</td>
<td>386</td>
</tr>
<tr>
<td>Oral cavity/pharynx</td>
<td>57</td>
<td>822</td>
<td>101</td>
</tr>
<tr>
<td>Lymph node</td>
<td>11</td>
<td>101</td>
<td>239</td>
</tr>
<tr>
<td>Musculoskeletal system</td>
<td>58</td>
<td>221</td>
<td>66</td>
</tr>
<tr>
<td>Endocrine glands</td>
<td>169</td>
<td>139</td>
<td>31</td>
</tr>
<tr>
<td>Haemopoietic system</td>
<td>111</td>
<td>72</td>
<td>146</td>
</tr>
<tr>
<td>Abdominal cavity</td>
<td>18</td>
<td>27</td>
<td>212</td>
</tr>
<tr>
<td>Urinary tract</td>
<td>71</td>
<td>89</td>
<td>72</td>
</tr>
</tbody>
</table>
Tumour Types in Anatomical Locations

Finally, a combined analysis of the occurrence of the different histological tumour types in the most common anatomical locations (>1%) was performed (Fig. 10).

Discussion

Veterinary cancer registries increase knowledge of the occurrence and distribution of tumours in companion animals over time. They may also enhance awareness of risk factors and allow improvement in prevention and treatment strategies. In addition, spontaneously arising companion animal tumours could serve as sentinels for human cancers.

Unfortunately, there are few animal cancer registries and many of them only cover short periods of time, mainly due to economic considerations. The advantage of the data presented here is that they were collected over more than 40 years, which has allowed us to construct a retrospective feline cancer registry over a longer period of time. To our knowledge, there is no other feline cancer registry that covers such a long time span (1965–2008) and contains such a large amount of data (51,322 cats and 18,375 tumours).

The main difficulty for population-based veterinary cancer registries is to identify the size of the population at risk. This also applies to the present project. Since cats do not have to be registered in Switzerland, there are only estimates as to the size of the feline population. Therefore, incidence rates cannot be calculated and we have to settle for proportional calculations from the available patient datasets.

Every animal cancer registry has struggled with this problem. In some studies the hospital-based patient dataset was used for calculations; in others, the population at risk was estimated using household or telephone surveys in a well-defined geographical area (Cotchin, 1952; Dorn et al., 1968a,b; Priester and Mantel, 1971; Patnaik et al., 1975; MacVean et al., 1978; Brønden et al., 2007; Egenvall et al., 2009; Vascellari et al., 2009; Nødtvedt et al., 2011a).

In addition, different inclusion criteria and methodologies as well as different tumour classifications were used. A comparison of the results from the few available registries is therefore difficult. We faced similar problems when generating our dataset from four sets of patient records. A number of pathologists had worked on the cases and not all of them applied the same criteria when it came to specifying the location of the tumour. This was particularly true for the location of leucosis (i.e. lymphoma) in cats. While some pathologists invariably ascribed leucosis in cats to an ‘unknown’ location, others described the location as ‘bone marrow’ and this was independent of the sample source. To homogenize the definition of the location and to avoid confusion, we recoded all ‘bone marrow’ locations as ‘unknown’. We did not, however, recode those cases of leucosis in which another, specific location of the tumour tissue was indicated. Among veterinary pathology cancer registries there seems to be some uncertainty concerning tumours that may be multicentric, such as lymphoma. In one registry this diagnosis is integrated into ‘haemopoietic tissue’ (MacVean et al., 1978); in two others into ‘lymphoid tissue’ (Cotchin, 1952; Vascellari et al., 2009). One registry used the combination ‘haemopoietic/lymphoid’ (Priester and Mantel, 1971) and the registries of Dorn et al. (1968a,b) just used the term ‘lymphosarcoma’ without additional statements as to location.

A similar problem was encountered with the diagnosis ‘fibrosarcoma’ in the subcutaneous tissue. Some pathologists reported ‘skin’ as the location since a skin biopsy sample was taken; others reported ‘soft tissue’. Here as well, we unified the location and recoded the ‘skin’ locations to ‘soft tissue’.

The criterion for including a patient record in our dataset was that a post-mortem investigation followed by histopathology, biopsy or cytology examination had been performed. The number of submissions increased markedly when biopsy analyses grew in popularity. Once the different methodologies were established, the proportion of tumours diagnosed remained stable. The proportion of tumours in biopsy...
**Fig. 10.** The most common tumour locations (>1%) and the corresponding histological tumour types in these locations. Diagnoses with a frequency of <1% were combined into 'other tumours'. Circle and segment dimensions correspond to the proportions in the overall location/tumour type count.

***Circle segment values are given as percentage and only values above 1 are specified***

Fig. 10. The most common tumour locations (>1%) and the corresponding histological tumour types in these locations. Diagnoses with a frequency of <1% were combined into 'other tumours'. Circle and segment dimensions correspond to the proportions in the overall location/tumour type count.
and cytology specimens was higher than in post-mortem examinations, because such samples were taken because of the clinical suspicion of a tumour. Based on all of the specimens analysed, 34.97% of all cats were found to have a tumour and most tumours were malignant (80.32%). A relatively low tumour rate with a high malignancy rate has also been described in other studies (Dorn et al., 1968a; MacVean et al., 1978; Vascellari et al., 2009).

Our dataset showed that no other breed had significantly higher odds of developing a tumour than the European shorthair cat. However, there were several breeds that had significantly lower ORs. Not many studies have focused on the frequency of tumours in different feline breeds and this is mainly due to a limited number of patients and breeds in the datasets. Patnaik et al. (1975) investigated non-haemopoietic neoplasms in feline necropsy examinations and found a higher tumour incidence in domestic shorthair, Persian and Himalayan cats compared with Siamese cats. Priester and Mantel (1971) found that domestic shorthair cats had a slightly higher risk than Persian and Siamese cats and in a study in Northern Italy, purebreds were found to have a higher risk of developing malignant tumours than crossbreeds (Vascellari et al., 2009). Every study shows a different result, making a comparison with our results very difficult.

Our data show that the odds of a cat developing a tumour increased with age, peaked at 16 years of age and then slightly decreased. Similar data have been published with age peaks at 14 (Patnaik et al., 1975) and 12 (Vascellari et al., 2009) years, respectively. Other registries described an increasing tumour risk with increasing age of the cat (Cotchin, 1952; Priester and Mantel, 1971).

In our data we found a clear difference in tumour frequencies between neutered and entire cats, with higher odds of developing a tumour in entire cats, both for males and females. To our knowledge there is no other publication that compares tumour occurrence in entire and neutered cats. However, there are publications on the differences between male and female cats. Our analyses reveal higher odds of female cats developing a tumour compared with male cats. This is in accordance with the studies of Patnaik et al. (1975) and Vascellari et al. (2009), which showed that female cats have a higher risk of developing a tumour than do males. Priester and Mantel (1971) found no gender difference when looking at all tumours, but a higher risk for male cats (not significant) with regard to malignant tumours.

Concerning tumour type and anatomical location, we are in agreement with the available registries that the most common tumour types are epithelial, mesenchymal or haemopoietic/lymphoid and the most common locations are skin and connective tissue, mammary gland and lymphoid/haemopoietic tissue (Dorn et al., 1968a,b; Priester and Mantel, 1971; Patnaik et al., 1975; MacVean et al., 1978; Vascellari et al., 2009). In earlier studies lymphomas were diagnosed more often, probably because the disease was more common, owing to the fact that there was no vaccination for feline leukaemia virus available at that time. There is a bias in these proportions, because tumours of the skin, connective tissue and female sexual organs (i.e. mammary gland) are more easily detected by physical examination than other tumours, where more advanced technological investigations are necessary.

The statistical evaluation of sex and breed in our dataset shows the importance of the inclusion of confounding factors. The bivariate analysis differs from the results of the multiple logistic regressions. In a retrospective study, however, one has to work with the information that exists and the number of available factors is normally limited. To find out which factors may contribute to the development of tumours (e.g. age at castration, nutrition or other diseases), it is advisable for future data registration to register as much information as possible.

In order to shed more light on the role of breed, age, sex and other factors in tumour formation, more and better quality information is necessary. Furthermore, to compare frequency rates of cancer among different countries or regions, uniform inclusion criteria as well as a specific international classification should be applied.

It would be desirable to compare incidence rates of cancer in companion animals with those of their human counterparts. Such comparisons would be valuable, but for this it is necessary to know the number of animals at risk. In Switzerland, such numbers are available for dogs, because it has been mandatory to have an animal identification number (microchip) since 2006. This should also be required for cats.

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Conflict of Interest Statement
The author(s) declare no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

References
Swiss Feline Cancer Registry

