ONCOLOGY OF THE SUGAR GLIDER (PETAURUS BREVICEPS): A COMPREHENSIVE REVIEW

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INTRODUCTION

The sugar glider (Petaurus breviceps) is a small, nocturnal marsupial originally from New Guinea and Australia (Campbell et al., 2019; Varriale et al., 2019). These animals are kept as an exotic pet in several countries such as Italy (Varriale et al., 2019) and the United States (Campbell et al., 2019). Therefore, several studies have investigated important aspects of husbandry such as nutrition (Dierenfeld, 2009) and behavioural aspects (Mallick et al., 1994). Work has also been published on medical aspects such as common emergencies (Lennox, 2007; McLaughlin and Strunk, 2016), common procedures (Johnson-Delaney, 2006), surgical procedures (Morges et al., 2009; Miwa and Sladky, 2016) and diagnostic approaches (Evans and Souza, 2010). Cusack and colleagues (2016) published a case of bilateral hydronephrosis, while Johnson-Delaney and Lennox (2017) investigated reproductive disorders. Other conditions, where case reports or series were published, include pulmonary hyalinosis (Sokol...
et al., 2017), zoonoses (Pignon and Mayer, 2011), toxoplasmosis (Barrows, 2006) and cancer (Gentz et al., 2003; Sokol et al., 2017; Son et al., 2021). Several cases of neoplasia in sugar gliders have been described. Gentz and colleagues (2003) described 33 cases of neoplastic lesions of different histological types. In a more recent retrospective study, three cases of cancer in gliders were identified (Sokol et al., 2017). These studies did, however, not describe the case characteristics, such as symptoms and treatment in detail. Relevant details have been described in single case reports (Churgin et al., 2015; Chen et al., 2018). To this date, no review has been published. Therefore, this paper aims to provide a comprehensive review of the current knowledge of cancer in the sugar glider.

**SEARCH STRATEGY AND LITERATURE INCLUSION**

The Medline database (through PubMed) was searched using the keywords “Sugar glider*” (103 results) and “Petaurus” (85 results). Additionally, Google Scholar was searched using “Sugar glider tumor” (724 results), “Sugar glider cancer” (1970 results), “Petaurus tumor” (520 results) and “Petaurus cancer” (453 results). The titles of the publications in the search results were screened for potential eligibility for inclusion. The abstracts of these selected papers were read and the papers were included if they (1) described cancer in at least one sugar glider, (2) they mentioned at least basic information about the animal, (3) mentioned at least basic information about the disease and (4) mentioned at least basic information about the treatment and outcome. Relevant information was then extracted from the publication.

**IDENTIFIED LITERATURE**

Eight single case reports were identified that met the inclusion criteria (Hough et al., 1992; Marrow et al., 2010; Keller et al., 2014; Rivas et al., 2014; Churgin et al., 2015; Lindemann et al., 2016; Chen et al., 2018; Son et al., 2021). The extracted data is shown in Table 1. Two case series (Gentz et al., 2003; Sokol et al., 2017) described several cases retrospectively, but did not meet the inclusion criteria because they did not report any information on the treatment pursued. No other case series were identified. Additionally, no studies investigating any risk factors for neoplastic disease in sugar gliders were identified. Finally, no prospective trials were identified that assessed potential treatment strategies.

**CASE CHARACTERISTICS AND TREATMENT**

The ages of the animals at presentation ranged from 4 (Hough et al., 1992) to 15 years (Lindemann et al., 2016), while the average age was 8.5 years. Three out of the eight animals were male. Little additional consistent information about the animals was mentioned. Two cases of mammary (adenocarcinoma were reported (Keller et al., 2014; Churgin et al., 2015). Other types of cancer ranged from lymphosarcoma (Hough et al., 1992) to hemangiosarcoma (Rivas et al., 2014). In the majority of cases, no metastases were reported. Symptoms were very variable and depended on the type and location of a tumor. Likewise, the treatment also varied significantly according to the specific case. However, surgical removal of the primary tumor was performed in several cases (Keller et al., 2014; Rivas et al., 2014; Chen et al., 2018). In several cases, antibiotic treatments were also initiated. It is also clear that pain management is very important.

Unfortunately, in five cases (Hough et al., 1992; Marrow et al., 2010; Keller et al., 2014; Churgin et al., 2015; Lindemann et al., 2016), the animal was eventually euthanized at the time the case was published. In one further case, the animal died (Son et al., 2021). In only two cases, the glider was alive without signs of cancer (Rivas et al., 2014; Chen et al., 2018).
<table>
<thead>
<tr>
<th>Ref.</th>
<th>Age</th>
<th>Sex</th>
<th>Cancer type</th>
<th>Metastasis</th>
<th>Symptoms</th>
<th>Treatment</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hough et al., 1992</td>
<td>4 yrs</td>
<td>M</td>
<td>Cutaneous lymphosarcoma</td>
<td>Lymph nodes Sinosoids of the spleen</td>
<td>Initial Suppurating ulcer right hind leg Small vesicles around pinnae Swollen digits Day 7 Reduced swelling digits Areas with vesicles increased in size Day 18 Extended limb ulceration Most digits swollen Nodules on trunk skin</td>
<td>Initial (for diagnosis of dermatitis / infection) Lincomycin (30 mg / day) Metacresolsulphonic acid (topical) Day 7 (for diagnosis of dermatitis / infection) Debridement of ulcer Amoxycillin (30 mg / day) Topical gentamicin Power containing zinc bacitracin (250 U/g) Neomycin sulphate 5 mg/g Plymixin B sulphate 5000 U/g Day 18 (for diagnosis of dermatitis / infection) Metronidazol (80 mg/kg oral / day)</td>
<td>Euthanized 5 days after day 18 treatment</td>
</tr>
<tr>
<td>Marrow et al., 2010</td>
<td>10 yrs</td>
<td>M</td>
<td>Paracloacal transitional cell carcinoma with squamous differentiation</td>
<td>None identified</td>
<td>Initial No clinical signs Pericloacal mass 5 months Self-mutilation cloacal skin Tenesmus Reduced food intake Large, firm mass Abdominal distention</td>
<td>Initial Enrofloxacin (5 mg/kg orally every 12 hours for 10 days)</td>
<td>Euthanized 5 months after initial presentation</td>
</tr>
<tr>
<td>Keller et al., 2014</td>
<td>9 yrs</td>
<td>F</td>
<td>Mammary carcinoma</td>
<td>None identified</td>
<td>Initial Subcutaneous mass right caudal abdomen Days after surgery at day 5 Self-mutilation of tail</td>
<td>Initial Meloxicam (0.5mg/kg oral, once a day) Day 5 Surgical excision 150 Gy of strontium-90 radiation therapy</td>
<td>Euthanized within 14 days after the surgery</td>
</tr>
<tr>
<td>Ref.</td>
<td>Age</td>
<td>Sex</td>
<td>Cancer type</td>
<td>Metastasis</td>
<td>Symptoms</td>
<td>Treatment</td>
<td>Outcome</td>
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<tr>
<td>Rivas et al., 2014</td>
<td>11 yrs</td>
<td>F</td>
<td>Dermal hemangiosarcoma</td>
<td>None identified</td>
<td>Initial No overt clinical signs Lesion on right patagonium Day 9 Increased size of lesion</td>
<td>Initial (for diagnosis of infected wound) Meloxicam (0.2 mg/kg, orally, every 24 hours, for 10 days Trimethoprim-sulfamethoxazole (15 mg/kg, orally, every 12 hours) Day 9 Surgical excision Post-operative care Enrofloxacin (10 mg/kg, orally, every 24 hours for 7 days) until day 28 after presentation Meloxicam (0.2 mg/kg, orally, every 24 hours for 4 days) until day 28 after presentation</td>
<td>No local or systemic sign of disease after 1 year</td>
</tr>
<tr>
<td>Churin et al., 2015</td>
<td>9 yrs</td>
<td>F</td>
<td>Mammary adenocarcinoma</td>
<td>Sublumbar Pouch lymph node Axillary lymph node Lung</td>
<td>Initial Lethargy Partial anorexia Mass within the pouch 6 months Weight loss Growth of pouch mass 7 months Inability to bear weight on right rear leg Growth of pouch mass</td>
<td>No specific treatment</td>
<td>Euthanized 7 months after initial presentation</td>
</tr>
<tr>
<td>Linde-mann et al., 2016</td>
<td>15 yrs</td>
<td>F</td>
<td>Adrenocortical carcinoma Hepatocellular carcinoma</td>
<td>None identified</td>
<td>Initial Diarrhea Weight loss Mass in midabdomen Circling to the right Impaired vision 72 hours Lethargy Circling to the right Impaired vision</td>
<td>Fluid therapy 40 mL/kg subcutaneously 2.5% dextrose Vitamin B complex 0.05 mL subcutaneously Amoxicillin-clavulanic acid 12.5 mg/kg orally, every 12 hours for 10 days Prednisolone 0.2 mg/kg, orally every 12 hours</td>
<td>Euthanized 72 hours after presentation</td>
</tr>
<tr>
<td>Ref.</td>
<td>Age</td>
<td>Sex</td>
<td>Cancer type</td>
<td>Metastasis</td>
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<tr>
<td>Chen et al., 2018</td>
<td>4 yrs.</td>
<td>M</td>
<td>Paracloacal gland carcinoma</td>
<td>None identified</td>
<td>Initial Self-mutilation cloacal region</td>
<td>Correction of husbandry Enrofloxacin 5mg/kg orally, twice a day Metronidazole 25mg/kg orally, twice a day Meloxicam 0.2mg/kg orally, once a day Nystatin 2000 IU/kg orally, twice a day E-collar (one month)</td>
<td>Alive 515 days following surgery</td>
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<td></td>
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<td>Day 178 Vocaulation during elimination</td>
<td>Day 178 E-collar Tramadol 2mg/kg orally, twice a day Meloxicam 0.2mg/kg orally, once a day Sulfamethoxazole/trimethoprim 15mg/kg orally, twice a day Metronidazole 25mg/kg orally, twice a day Meloxicam 0.2mg/kg orally, once a day Sulfamethoxazole/trimethoprim 15mg/kg orally, twice a day Metronidazole 25mg/kg orally, twice a day</td>
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<td></td>
<td></td>
<td>Day 217 Swelling Right side cloaca Reduced activity Reduced appetite</td>
<td>Day 217 E-collar Tramadol 2mg/kg orally, twice a day Meloxicam 0.2mg/kg orally, once a day Sulfamethoxazole/trimethoprim 15mg/kg orally, twice a day Metronidazole 25mg/kg orally, twice a day Meloxicam 0.2mg/kg orally, once a day Sulfamethoxazole/trimethoprim 15mg/kg orally, twice a day Metronidazole 25mg/kg orally, twice a day</td>
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<td></td>
<td>Day 229 Swelling right side cloaca Intensified straining during elimination with blood</td>
<td>Four weeks after day 229 Vocaulation during elimination</td>
<td>Day 229 Surgical removal of glands Ciprofloxacin 10mg/kg orally, twice a day Meloxicam 0.2mg/kg orally, once a day Metronidazole 25mg/kg orally, twice a day Tramadol 2mg/kg orally, twice a day Lactulose 0.5mg/kg orally, twice a day (7 days) E-collar</td>
</tr>
<tr>
<td>Nguyen et al., 2021</td>
<td>6 yrs.</td>
<td>F</td>
<td>Disseminated histiocytic sarcoma</td>
<td>Urinary bladder Medial iliac lymph nodes Pericloacal mass Liver Spleen Small intestine Uterus Left ovary</td>
<td>Initial Swelling at pouch</td>
<td>None mentioned</td>
<td>Died 8 days after initial presentation</td>
</tr>
</tbody>
</table>
DISCUSSION AND CONCLUSION

A relatively small number of case reports was identified about cancer in sugar gliders. This means that there is a clear lack of external and internal validity in the current body of literature. There was a wide range of ages at presentation. However, with an average of 8.5 years, it could be stated that it seems that age is a potential risk factor for cancer in gliders. There was a relative equal distribution between males and females. However, based on these limited cases, it is very difficult to make sound conclusions about potential risk factors and epidemiology of the condition.

There were several different histological types of cancer described in the case reports. Previous case series have reported more cases and could provide a better overview of the most common types of cancer that occur in sugar gliders (Gentz et al., 2003; Sokol et al., 2017). In most cases, there were no metastases reported. However, it is not clear which mechanisms play a role in metastasizing in this species and which types may be predisposed to metastasize.

Several treatment strategies were utilized depending, amongst others, on the type and location of the primary tumour. Based on the current results, it does not seem feasible yet to develop standardized, evidence-based treatment guidelines for specific cancer types. It is, however, clear that surgical excision is an important component of several treatment schedules. Unfortunately, most of the animals were euthanized or died, while only two animals were alive at the time of publication of their case. This confirms that further research is required to assess and establish therapeutic strategies.

Further research could start with a better reporting of cases. An important role could be played by communities of owners. These communities are very active in discussing health problems with their pets. They could be approached to assist in the recording of cases. Additionally, retrospective studies could be conducted of cases already seen in veterinary practices. Finally, prospective clinical trials should be conducted to establish effective and save therapeutic strategies.

Relatively few case reports were identified regarding cancer in sugar gliders. There was a large variation in the age at which the animals were diagnosed and in the tumour types that were described. In several of the published cases, surgical removal of the primary tumour was performed. This was often complemented with pain management. Unfortunately, prognosis was very poor, since only two out of eight animals were alive at the time of publication. Further research is required to get more insight into the epidemiology and characteristics of cancer in this species.

CONFLICT OF INTEREST

The author declared that there is no conflict of interest.

REFERENCES


ONKOLOGIJA MALOG ZLATNOG LETAŠA (PETAURUS BREVICEPS): SVEOBHUVTNI PREGLED

SAŽETAK


Ključne riječi: Karcinom, slučajevi, epidemiologija, mali zlatni letaš, terapija