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ARTICLE

Use of computed tomography to determine body surface area and *K*-constant in Atlantic Stingrays for chemotherapeutic dosing

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Abstract

Objective: The objective of this study was to use body surface area (BSA) obtained via computed tomography (CT) to calculate a species-specific shape constant (*K*) and provide a formula for BSA based on body weight (BW) in Atlantic Stingrays *Hypanus sabina*. Ultimately, this information can be used to more accurately calculate chemotherapeutic doses and other metabolic-related measures.

Methods: Six deceased Atlantic Stingrays of unknown age and with a range of sizes were collected during a natural mortality event and underwent CT scans. Following the scans, three-dimensional surface models were created from the imaging data to measure BSAs and derive a BSA formula based on BW. Nonlinear regression analysis of BSA versus thawed BW was performed, and a species-specific formula was derived.

Result: Body surface area (mean ± standard deviation) was 2015.01 ± 1115.02 cm^2 (median = 1841.40 cm^2; range = 844.2–4043.12 cm^2). The calculated *K*-constant was 14.9 for the six Atlantic Stingrays, and the CT-derived BSA formula was as follows: BSA (cm^2) = 14.9 × (BW, g)$^{2/3}$.

Conclusion: These results provide a method for calculating BSA in Atlantic Stingrays. The CT-derived BSA formula can be used for allometric dosing of chemotherapeutic agents and other drugs in a clinical setting; in a broader sense, the formula can be applied to studies of nutrition, metabolic rate, and physiology.

KEYWORDS

Atlantic Stingray, body surface area, computed tomography, *Hypanus sabina*, *K*-constant

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INTRODUCTION

Elasmobranchs comprise approximately 1200 species of sharks, skates, rays, and chimaeras. Some of these species are displayed in zoological and aquarium institutions to serve as ambassadors for their species and as ex situ breeding populations. This is particularly important because many elasmobranchs are threatened or endangered (Dehart 2004; Jorgensen et al. 2022). Due to limited reporting of neoplasia in this class of animals, it has previously and incorrectly been assumed that they do not experience neoplasia (Ostrander et al. 2004). However, according to the Registry for Tumors in Lower Animals, the Exotics Species Cancer Research Alliance database, two different retrospective studies of disease, and published case reports, elasmobranchs do experience neoplasia in a variety of body systems (Prieur et al. 1976; Wolke 1976; Woodhead and Woodhead 1979; Berzins and Hovland 1999; Pereira and Peleteiro 2002; Borucinska et al. 2003, Borucinska et al. 2004; Ostrander et al. 2004; Waldoch et al. 2010; Garner 2013; Manire et al. 2013; Robbins et al. 2014; Jafarey et al. 2015; Nau et al. 2016; Stidworthy et al. 2017; Strobel et al. 2017; Camus et al. 2018; Stilwell et al. 2019; Gerlach et al. 2021; Shocklee et al. 2021; Perry et al. 2022; Archer et al. 2023). Depending on the retrospective study, prevalence of neoplasia in elasmobranchs ranges from 0.5% to 4.0% (Garner 2013; Stidworthy et al. 2017). Rates may be higher, but the published literature is still relatively sparse. Regardless, improved therapeutic options are needed for those elasmobranchs that do develop neoplastic disease.

Chemotherapeutic drug usage in zoological, aquatic, and exotic species is limited in comparison to usage in domestic animals (Hahn 2005). Due to the narrow margin of safety in chemotherapeutic medications, this group of drugs is typically dosed in milligrams per square meter (mg/m^2) of body surface area (BSA) rather than body mass or weight. The BSA is often estimated with formulas involving morphometric data (i.e., body weight [BW, g] and body length). The equation used currently in veterinary medicine is extrapolated from the Dubois equation in human medicine: $BSA = K \times BW^{2/3}$ (Hahn 2005; Fancher et al. 2016; Hepps Keeney et al. 2021), where K represents a shape constant that is unique to each species. Various methods have been used to determine K. The most historic is the tape method, in which tape is applied to the entire animal's surface area and the surface areas of all the tape pieces are combined for a total surface area; the most advanced method involves computed tomography (CT) of live animals or cadavers (Hepps Keeney et al. 2021). In veterinary medicine, the K-constant has been identified for dogs *Canis familiaris*, rats *Rattus norvegicus domestica*, rabbits *Oryctolagus cuniculus*, guinea pigs *Cavia porcellus*, ferrets *Mustela furo*, homing pigeons *Columba livia*, and bearded dragons *Pogona vitticeps*, among others (Price and Frazier 1998; Gouma et al. 2012; Zehnder et al. 2012; Perez et al. 2014; Jones et al. 2015; Hepps Keeney et al. 2021; Itoh et al. 2021). Calculation of the K-constant in fish has been limited to two fusiform teleosts, specifically the Atlantic Salmon *Salmo salar* and Common Carp *Cyprinus carpio* (Ling et al. 2008; Frederick et al. 2017).

We have found only one case report of allometric dosing of an antineoplastic agent for an elasmobranch. A Cownose Ray *Rhinoptera bonasus* with lymphosarcoma received oral lomustine dosed at 60–70 mg/m^2 (Perry et al. 2022). The calculation of BSA in that case was based on the K-constant for dogs (S. Perry, Mississippi Aquarium, personal communication). The purpose of this study was to use morphometric data obtained via CT to calculate the K-constant and provide a formula for BSA in Atlantic Stingrays *Hypanus sabina* to more accurately calculate chemotherapeutic drug dosages.

Impact Statement

Chemotherapeutic agents and other drugs that are administered based on body surface area can be more appropriately dosed in Atlantic Stingrays and other similarly shaped species with the identified K-constant and species-specific body surface area equation based on body weight.

METHODS

Animals

Deceased wild Atlantic Stingrays were collected during a natural mortality event in Carteret County, North Carolina, by Fort Macon State Park staff. These animals were donated to the Center for Marine Sciences and Technology at North Carolina State University for research and teaching purposes. Specific age and health status of the animals were unknown, and six individuals were intentionally selected for maximum variety in size and even distribution of sex for this study (Table 1). Carcasses were obtained under North Carolina Division of Marine Fisheries Scientific or Educational Activity Permit 1791359. The Atlantic Stingrays were frozen for approximately 6 months prior to initiation of this study.

TABLE 1 Morphometric and calculated data for individual Atlantic Stingrays. BSA, body surface area; DW, disc width; F, female; M, male; SD, standard deviation; TL, total length (snout to distal tail tip); Wt, weight.

Fish ID or statistic	Sex	Thawed Wt (g)	DW (cm)	TL (cm)	BSA (cm^2)	*K*-constant
Ray 1	M	390	23	56	844	15.8
Ray 2	F	730	27.5	66	1245	15.3
Ray 3	M	1340	33	69	1765	14.5
Ray 4	F	1460	34	80	1917	14.8
Ray 5	M	2000	36	86	2274	14.3
Ray 6	F	4540	47	105	4043	14.7
Mean		1743	33	77	2015	14.9
SD		1482	8	17	1115	0.55
Median		1400	33.5	74.5	1841	14.8

Examination and imaging

Animals were thawed for 36 h prior to CT imaging for assessment of BSA. Once thawed, animals were physically examined by one investigator (L.M.) to identify any external abnormalities that could impact body shape and assessment. Body weight and disc width (measured at the widest point, perpendicular to the spinal column) were obtained.

For CT, animals were patted dry with towels and placed in ventral recumbency on foam (polyurethane foam sheet, 40.64 × 53.34 × 2.54 cm [16 × 21 × 1 in]; DECOHS brand). Drying of the patients and the use of foam were critical to creating three-dimensional (3-D) reconstruction for assessment of BSA by facilitating segmentation of the stingrays. Without drying and the placement of foam, it was not possible to segment the stingrays from the table with the software for BSA calculation. Transverse images with a 1-mm slice thickness were acquired at 130 kilovoltage peak and 130 mA and obtained from the most rostral midline to the tip of the tail with a 64-slice helical CT scanner (SOMATOM Perspective; Siemens Healthcare).

Three-dimensional CT reconstruction

The CT images were reconstructed and downloaded in a bone window reconstruction algorithm (window width = 3500 Hounsfield units [HU]; window level = 400 HU) and were analyzed with CT image analysis software (Mimics Innovation Suite; Materialise NV). A 3-D surface model was created for each Atlantic Stingray by use of a minimum threshold value of −800 HU with no upper limit so that densities outside the animal were excluded (Figure 1). Air in each animal (e.g., spiracles, oral cavity, minor bite defects in two individuals) was manually removed with a tracing tool as previously described (Jones et al. 2015). The software then calculated BSA (mm^2) for each individual from a triangle mesh overlay after the surface model was created.

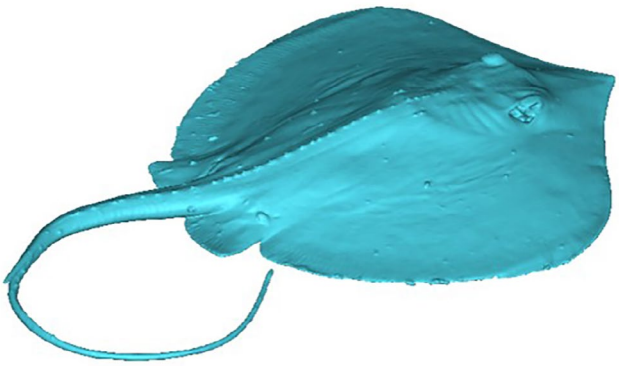


FIGURE 1 Three-dimensional reconstruction of a female Atlantic Stingray obtained using Mimics Innovation Suite software (Materialise NV) for calculation of body surface area.

Statistical analysis

Statistical analyses were performed using a commercial program (Statistics Kingdom; http://www.statskingdom.com). The BSA from 3-D reconstruction software and the BW were used to calculate the *K*-constant for all individuals. The BSA was plotted against $BW^{2/3}$ using a nonlinear regression, and the R^2 and standard deviation (SD) of the regression were calculated to assess goodness of fit. Descriptive data are reported as the mean ± SD along with the median and range.

RESULTS

Refer to Table 1 for BW, disc width, total length, BSA, and *K*-constant data. The CT-derived BSA formula for Atlantic

Stingrays was as follows: BSA (cm^2) = 14.9 × $BW^{2/3}$, where BW is measured in grams (BSA in m^2 = [BSA in cm^2/10,000]). The R^2 and SD of the nonlinear regression were 0.99 and 45.94, respectively. The *K*-constant for males was 14.9 ± 0.81 (median = 14.52; range = 14.33–15.81), and the *K*-constant for females was 15.0 ± 0.32 (median = 14.89; range = 14.74–15.35).

DISCUSSION

This study used 3-D CT reconstruction of Atlantic Stingray cadavers to identify BSA as well as the *K*-constant for calculation of BSA using BW. This methodology has been used in several species, and our study represents an extension of the methodology to an elasmobranch species with an extreme dorsoventrally compressed body configuration (Zehnder et al. 2012; Jones et al. 2015; Hepps Keeney et al. 2021; Itoh et al. 2021; Hinkle et al. 2023).

The *K*-constant for Atlantic Stingrays (14.9) is considerably higher than the *K*-constants reported for mammals, including domestic dogs (10.00), domestic rabbits (9.90), ferrets (9.94), rats (9.83), and guinea pigs (8.37; Price and Frazier 1998; Gouma et al. 2012; Zehnder et al. 2012; Jones et al. 2015; Itoh et al. 2021). This value is also considerably higher than the *K*-constants reported in reptiles and amphibians, such as corn snakes *Pantherophis guttatus* (13.6), bearded dragons (11.6), and American bullfrogs *Lithobates catesbeianus* (8.4; Hepps Keeney et al. 2021; Calcagno et al. 2023; Hinkle et al. 2023). The *K*-constant closest to the value obtained for Atlantic Stingrays is that reported for Atlantic Salmon (13.9; Frederick et al. 2017). To our knowledge, Atlantic Stingrays have the highest identified *K*-constant based on BW of any vertebrate thus far reported. This is not surprising given their shape and marked dorsoventral compression. This also indicates that using BSA calculated with the *K*-constant of a mammal, reptile, amphibian, or even a teleost is not representative of the BSA for stingrays and other similarly shaped animals.

Only a small set of animals was available for research purposes because they were opportunistically obtained. Initially, this may be seen as a limitation. However, despite a 10-fold difference in weight (range = 390–4540 g), the SD for the *K*-constant was only 0.55, indicating low variability and high reliability across individuals of markedly varying sizes. Additionally, measures of variability in our study were similar to measures obtained from the use of identical methodology but with a larger sample size, indicating that a larger sample size likely would not have altered the *K*-constant result identified in this study (Hepps Keeney et al. 2021).

The equation for calculating BSA in Atlantic Stingrays as established within this paper permits the user to calculate BSA without the need for advanced imaging or expensive computer software. The results of our study have clinical applications to allometric dosing of chemotherapeutics, but in a broader sense they can be used for evaluation of metabolic rate, energetics studies, and ecological population health assessments and can be implemented in a variety of other contexts (Berman 2003; Glazier 2008; Burnett et al. 2019). The relatively high *K*-constant better reflects the general shape of this species and has clinical correlates to other dorsoventrally compressed animals.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest.

DATA AVAILABILITY STATEMENT

Data are available upon request from the Exotic Species Cancer Research Alliance and the corresponding author.

ETHICS STATEMENT

Approval of this project was received from North Carolina Division of Marine Fisheries Scientific or Educational Activity Permit 1791359.

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REFERENCES

Archer, K. R., Groll, T., Harvey, R. J., Thornton, S. M., Stidworthy, M. F., & Denk, D. (2023). Case series: Lymphoid neoplasia in three elasmobranch species. *Journal of Fish Diseases*, *46*, 273–279. https://doi.org/10.1111/jfd.13742

Berman, A. (2003). Effects of body surface area estimates on predicted energy requirements and heat stress. *Journal of Dairy Science*, *86*(11), 3605–3610. https://doi.org/10.3168/jds.S0022-0302(03)73966-6

Berzins, I. K., & Hovland, E. (1999). *Shark tumor—An oxymoron?* Proceedings of the International Aquatic Animal Medicine conference. https://www.vin.com/apputil/content/defaultadv1.aspx?pId=11122&meta=Generic&catId=29125&id=3981936

Borucinska, J. D., Harshbarger, J. C., & Bogicevic, T. (2003). Hepatic cholangiocarcinoma and testicular mesothelioma in a wild-caught Blue Shark, *Prionace glauca* (L.). *Journal of Fish*

Diseases, *26*(1), 43–49. https://doi.org/10.1046/j.1365-2761.2003.00435.x

Borucinska, J. D., Harshbarger, J. C., Reimschuessel, R., & Bogicevic, T. (2004). Gingival neoplasms in a captive Sand Tiger Shark, *Carcharias taurus* (Rafinesque) and a wild-caught Blue Shark, *Prionace glauca* (L.). *Journal of Fish Diseases*, *27*(3), 185–191. https://doi.org/10.1111/j.1365-2761.2004.00532.x

Burnett, J. D., Lemos, L., Barlow, D., Wing, M. G., Chandler, T., & Torres, L. G. (2019). Estimating morphometric attributes of baleen whales with photogrammetry from small UASs: A case study with blue and gray whales. *Marine Mammal Science*, *35*(1), 108–139. https://doi.org/10.1111/mms.12527

Calcagno, J. N., Nelson, N. C., Duke, E. G., & Harrison, T. M. (2023). Defining a species-specific *K* constant in American bullfrogs (*Lithobates catesbeianus*) through the use of computed tomography. *American Journal of Veterinary Research*, *84*(11), 1–5. https://doi.org/10.2460/ajvr.23.06.0131

Camus, A. C., Ibraheim, M. M., Alhizab, F. A., Aboellail, T. A., & Ibrahim, A. M. (2018). Poorly differentiated soft tissue sarcoma in an Arabian Carpet Shark *Chiloscyllium arabicum* (Gubanov): A case report. *Journal of Fish Diseases*, *41*(1), 181–185. https://doi.org/10.1111/jfd.12683

Dehart, A. (2004). Species selection and compatibility. In M. Smith, D. Warmolts, D. Thoney, & R. Hueter (Eds.), *The elasmobranch husbandry manual I: Captive care of sharks, rays and their relatives* (pp. 15–23). Ohio Biological Survey.

Fancher, K. M., Sacco, A. J., Gwin, R. C., Gormley, L. K., & Mitchell, C. B. (2016). Comparison of two different formulas for body surface area in adults at extremes of height and weight. *Journal of Oncology Pharmacy Practice*, *22*(5), 690–695. https://doi.org/10.1177/1078155215599669

Frederick, C., Brady, D. C., & Bricknell, I. (2017). Landing strips: Model development for estimating body surface area of farmed Atlantic Salmon (*Salmo salar*). *Aquaculture*, *473*, 299–302. https://doi.org/10.1016/j.aquaculture.2017.02.026

Garner, M. M. (2013). A retrospective study of disease in elasmobranchs. *Veterinary Pathology*, *50*(3), 377–389. https://doi.org/10.1177/0300985813482147

Gerlach, J. L., Stevens, N. B., Garner, M. M., LaDouceur, E. E. B., & Adams, L. M. (2021). *Primary hepatic neoplasia in three adult captive Bamboo Sharks* (Chiloscyllium plagiosum *and* Chiloscyllium punctatum). Proceedings of the International Aquatic Animal Medicine conference. https://www.vin.com/apputil/content/defaultadv1.aspx?pId=27093&catId=164678&id=10200661&ind=122&objTypeID=17&meta=Generic

Glazier, D. S. (2008). Effects of metabolic level on the body size scaling of metabolic rate in birds and mammals. *Proceedings of the Royal Society B*, *275*, 1405–1410. https://doi.org/10.1098/rspb.2008.0118

Gouma, E., Simos, Y., Verginadis, I., Lykoudis, E., Evangelou, A., & Karkabounas, S. (2012). A simple procedure for estimation of total body surface area and determination of a new value of Meeh's constant in rats. *Laboratory Animals*, *46*(1), 40–45. https://doi.org/10.1258/la.2011.011021

Hahn, K. A. (2005). Chemotherapy dose calculation and administration in exotic animal species. *Seminars in Avian and Exotic Pet Medicine*, *14*(3), 193–198. https://doi.org/10.1016/j.saep.2005.06.004

Hepps Keeney, C. M., Nelson, N. C., & Harrison, T. M. (2021). Use of computed tomography to determine a species-specific formula for body surface area in bearded dragons (*Pogona vitticeps*). *American Journal of Veterinary Research*, *82*(8), 629–633. https://doi.org/10.2460/ajvr.82.8.629

Hinkle, D. G., Nelson, N. C., Duke, E. G., & Harrison, T. M. (2023). Calculation of body surface area of corn snakes (*Pantherophis guttatus*) utilizing computed tomography. *American Journal of Veterinary Research*, *85*(2), 1–4. https://doi.org/10.2460/ajvr.23.09.0217

Itoh, T., Kawabe, M., Nagase, T., Endo, K., Miyoshi, M., & Miyahara, K. (2021). Body surface area measurements in male Hartley guinea pigs using a computed tomography scanner. *Journal of Veterinary Medical Science*, *83*(1), 142–145. https://doi.org/10.1292/jvms.20-0525

Jafarey, Y. S., Berlinski, R. A., Hanley, C. S., Garner, M. M., & Kiupel, M. (2015). Presumptive dysgerminoma in an Orange-spot Freshwater Stingray (*Potamotrygon motoro*). *Journal of Zoo and Wildlife Medicine*, *46*(2), 382–385. https://doi.org/10.1638/2014-0148R.1

Jones, K. L., Granger, L. A., Kearney, M. T., da Cunha, A. F., Cutler, D. C., Shapiro, M. E., Tully, T. N., & Shiomitsu, K. (2015). Evaluation of a ferret-specific formula for determining body surface area to improve chemotherapeutic dosing. *American Journal of Veterinary Research*, *76*(2), 142–148. https://doi.org/10.2460/ajvr.76.2.142

Jorgensen, S. J., Micheli, F., White, T. D., Van Houtan, K. S., Alfaro-Shigueto, J., Andrzejaczek, S., Arnoldi, N. S., Baum, J. K., Block, B., Britten, G. L., Butner, C., Caballero, S., Cardeñosa, D., Chapple, T. K., Clarke, S., Cortés, E., Dulvy, N. K., Fowler, S., Gallagher, A. J., … Ferretti, F. (2022). Emergent research and priorities for shark and ray conservation. *Endangered Species Research*, *47*, 171–203. https://doi.org/10.3354/esr01169

Ling, F., Wang, J. G., Li, A. H., Zhang, J. Y., Li, M., Gu, Z. M., & Gong, X. N. (2008). Determination of the surface area of Common Carp, *Cyprinus carpio* L. *Journal of Applied Ichthyology*, *24*(6), 690–693.

Manire, C. A., Clarke, A. C., Wert, D., & Landolfi, J. (2013). Lymphosarcoma in a captive Bonnethead Shark, *Sphyrna tiburo* (L.). *Journal of Fish Diseases*, *36*(4), 437–440. https://doi.org/10.1111/j.1365-2761.2012.01435.x

Nau, M. R., Gardiner, D. W., Nilson, E., Schmitt, T. L., Nollens, H. H., & St. Leger, J. (2016). Cutaneous malignant melanoma in a Haller's Round Ray *Urobatis halleri*. *Diseases of Aquatic Organisms*, *120*, 245–250. https://doi.org/10.3354/dao03029

Ostrander, G. K., Cheng, K. C., Wolf, J. C., & Wolfe, M. J. (2004). Shark cartilage, cancer, and the growing threat of pseudoscience. *Cancer Research*, *64*(23), 8485–8491. https://doi.org/10.1158/0008-5472.CAN-04-2260

Pereira, N. M., & Peleteiro, M. C. (2002). Osteoma in the skin of a Tawny Nurse Shark, *Nebrius ferrugineus* (Lesson). *Journal of Fish Diseases*, *25*(9), 505–567. https://doi.org/10.1046/j.1365-2761.2002.00397.x

Perez, C. R., Moye, J. K., & Pritsos, C. A. (2014). Estimating the surface area of birds: using the homing pigeon (*Columba livia*) as a model. *Biology Open*, *3*(6), 486–488. https://doi.org/10.1242/bio.20146999

Perry, S. M., Tims, M. B., Stacy, N. I., Dill-Okubo, J., Arnold, J., Ezell, T. M., & Delaune, A. J. (2022). *Diagnosis and management of multicentric lymphosarcoma in a Cownose Ray* (Rhinoptera *bonasus*). Proceedings of the International Aquatic Animal Medicine conference. https://www.vin.com/apputil/content/

defaultadv1.aspx?pId=28857&catId=191074&id=10902749&ind=59&objTypeID=17&meta=Generic

Price, G. S., & Frazier, D. L. (1998). Use of body surface area (BSA)-based dosages to calculate chemotherapeutic drug dose in dogs: Potential problems with current BSA formulae. *Journal of Veterinary Internal Medicine*, *12*(4), 267–271. https://doi.org/10.1111/j.1939-1676.1998.tb02121.x

Prieur, D. J., Fenstermacher, J. D., & Guarino, A. M. (1976). A choroid plexus papilloma in an elasmobranch (*Squalus acanthias*). *Journal of the National Cancer Institute*, *56*(6), 1207–1209. https://doi.org/10.1093/jnci/56.6.1207

Robbins, R., Bruce, B., & Fox, A. (2014). First reports of proliferative lesions in the Great White Shark, *Carcharodon carcharias* L., and Bronze Whaler Shark, *Carcharhinus brachyurus* Günther. *Journal of Fish Diseases*, *37*(11), 997–1000. https://doi.org/10.1111/jfd.12203

Shocklee, M. M., Stevens, B. N., Garner, M. M., & Adams, L. M. (2021). *Cephalic sarcoma with metastasis in an adult Swell Shark* (Cephaloscyllium ventriosum). Proceedings of the International Aquatic Animal Medicine conference. https://www.vin.com/apputil/content/defaultadv1.aspx?pId=27093&catId=164682&id=10200686&ind=108&objTypeID=17&meta=Generic

Stidworthy, M. F., Thornton, S. M., & James, R. (2017). A review of pathologic findings in elasmobranchs: A retrospective case series. In M. Smith, D. Warmolts, D. Thoney, R. Hueter, M. Murray, & J. Ezcurra (Eds.), *The elasmobranch husbandry manual II: Recent advances in the care of sharks, rays, and their relatives* (pp. 277–287). Ohio Biological Survey.

Stilwell, J. M., Camus, A. C., Zachariah, T. T., & McManamon, R. (2019). Disseminated lymphoid neoplasia and hepatoblastoma in an Atlantic Stingray *Hypanus sabinus* (Lesueur 1824). *Journal of Fish Diseases*, *42*, 319–323. https://doi.org/10.1111/jfd.12932

Strobel, M. M., Rosenberg, J. F., Haulena, M., Evans, H. M., Snyman, H. N., & Raverty, S. A. (2017). *Post-mortem diagnosis of lymphoma in a captive White-spotted Bamboo Shark* (Chiloscyllium plagiosum). Proceedings of the International Aquatic Animal Medicine conference. https://www.vin.com/apputil/content/defaultadv1.aspx?pId=18363&meta=Generic&catId=98265&id=7977791&ind=110&objTypeID=17

Waldoch, J. A., Burke, S. S., Ramer, J. C., & Garner, M. M. (2010). Melanoma in the skin of a Nurse Shark (*Ginglymostoma cirratum*). *Journal of Zoo and Wildlife Medicine*, *41*(4), 729–731. https://doi.org/10.1638/2010-0014.1

Wolke, R. E. (1976). A case report of an epidermal papilloma in *Mustelus canis*. *Journal of Wildlife Diseases*, *12*(2), 161–171. https://doi.org/10.7589/0090-3558-12.2.167

Woodhead, A. D., & Woodhead, P. M. J. (1979). A thyroid neoplasm in the Spiny Dogfish, *Squalus acanthias*. *Bull Mountain Desert Island Biological Laboratory*, *19*, 19–21.

Zehnder, A. M., Hawkins, M. G., Trestrail, E. A., Holt, R. W., & Kent, M. S. (2012). Calculation of body surface area via computed tomography-guided modeling in domestic rabbits (*Oryctolagus cuniculus*). *American Journal of Veterinary Research*, *73*(12), 1859–1863. https://doi.org/10.2460/ajvr.73.12.1859