Calculation of Body Surface Area Using Computed Tomography-Guided Modeling in Dogs and Cats

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Background

$$BSA = \frac{K \cdot W^{2/3}}{10000}$$

Cancer chemotherapy is calculated using an estimation of body surface area (BSA). The current formula is shown at left, where K is the shape constant (10.1 for dogs, 10.0 for cats), and W is the weight in grams.

This formula was derived many years ago using only a few dogs. Shape and conformational differences among dogs are vast, and using one uniform shape constant may not be accurate.

Computed tomography (CT) can help accurately determine BSA for various sized dogs and cats to modify the current equation.

Methods

Full-body CT scans were retrieved from animals requiring diagnostic imaging from the University of Missouri—Columbia and the University of Minnesota.

XiO

Series of 1 or 3 mm were transferred to XiO radiation treatment planning software (release 2.6). The patient was contoured, then edited in each 2D plane. A 1 mm thick bolus was applied around each 2D image and exported to Excel. BSA was calculated by adding all of the boluses and multiplying by 0.1-0.3 cm (depending on slice thickness) to transform the length into an area. The result was divided by 10,000 to convert from cm^2 to m^2.

RS

Series of 3 mm were transferred to RayStation radiation treatment planning software (release 4.7.2.5). The patient was contoured using the grey level threshold function (-250 HU to 1000 HU), then edited in each 2D plane. A 1 mm outer and inner wall was applied, and these values were averaged to find BSA.

Patient volume was found and compared to patient weight to ensure contour accuracy. A 50 cm cube was also contoured, and the BSA and volume was found in RayStation.

Height and weight were obtained both retrospectively and prospectively. Retrospectively, height was obtained via CT using an estimation of inter-cranial distance[1]. Length was obtained by measuring from the first instance of the manubrium to the last instance of the ischium. Prospectively, height and length were measuring on the day the CT scan was performed. Height was measured at the highest point of the shoulders. Length was measured from manubrium to the ischium.

[1]Chrószcz et. al. Anat Histol Embryol. 2007 Aug;36(4):269-71.

Acknowledgments

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Accuracy of Contours

There was no significant difference between patient weight and CT-estimated weight (p=0.482). A 50 cm cube was also accurately contoured for BSA (14992 cm^2 CT vs. 15000 cm^2 measured) and volume (126217 cm^3 CT vs. 125000 cm^3 measured).

XiO

Retrospectively, XiO was used to find the BSA for 12 dogs. Initially, we evaluated the same scan using both 1 mm and 3 mm slice thickness. The result returned a percent difference of 0.2%. From this point, we continued using either 2 or 3 mm slice thickness.

A patient's BSA was evaluated pre– and post-amputation of the right forelimb. The post-amputation scan returned a higher BSA than the pre-amputation scan due the positioning of the patient and the limitations of XiO. Additionally, only 2 scans could be evaluated per day at best using XiO. Therefore, alternative programs were explored.

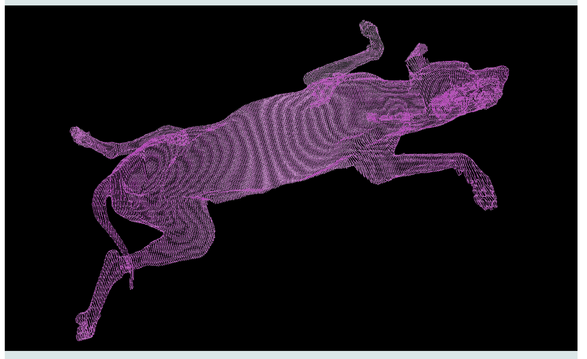

Figure 1—3D reconstruction for confirmation of body outline in XiO.

XiO vs. RayStation

Due to the limitations described above, a new treatment planning software, RayStation, was used. An open source program, Slicer, was also evaluated. The inordinate amount of time associated with this program (up to 1 week per scan) made its use impractical.

The original 12 scans from XiO were evaluated using RayStation. No significant difference was found in BSA using RayStation vs. XiO (p=0.308). Therefore, RayStation was used to further evaluate additional full-body CT scans both retrospectively and prospectively.

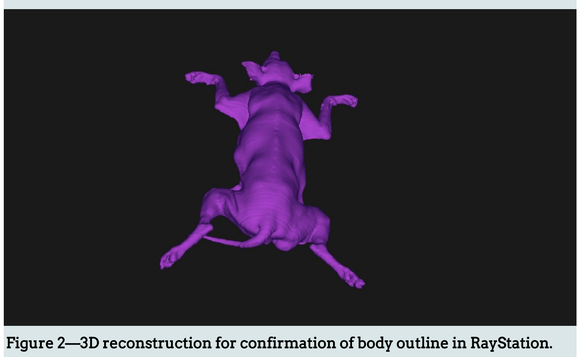

Figure 2—3D reconstruction for confirmation of body outline in RayStation.

RayStation

Retrospectively, 25 scans from dogs were evaluated in RayStation. Prospectively, 2 scans from dogs and 2 scans from cats were evaluated. After the first 18 dogs, there was a significant difference between RayStation vs. the formula (p=0.023). After an additional 9 scans, this comparison lost significance (p=0.155). Therefore, we plan to expand this study to include more scans to confirm or deny the difference.

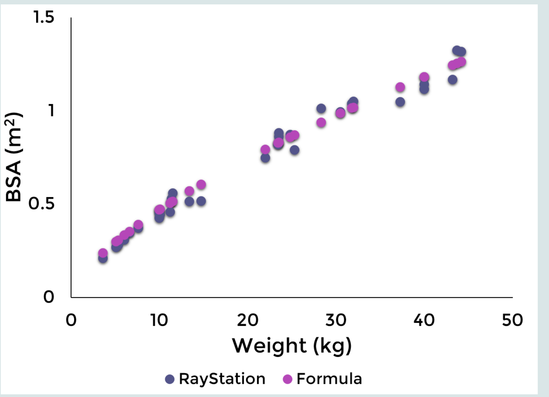

Figure 3—BSA vs. weight. Note that at several intervals, dogs of the same weight have different BSA, supporting that factors other than weight should be used for this calculation.

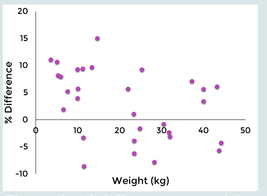

Figure 4—% difference vs. weight. As there is no pattern in variation, changing the K constant may not be enough to modify the formula.

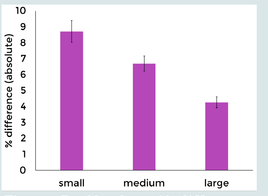

Figure 5—Absolute % difference per weight category. Small (<10 kg), medium (10-30 kg), and large (>30 kg).

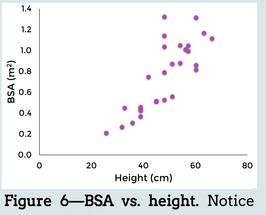

Figure 6—BSA vs. height. Notice the marked variability in height among dogs of similar BSA, which illustrates the differences in shapes among dogs.

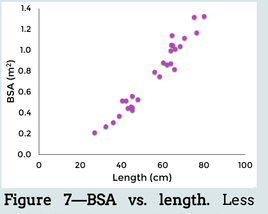

Figure 7—BSA vs. length. Less variability is seen in length vs. height, therefore, length may be a superior measure of shape. This is supported by past publications.

Discussion

Overall, the CT-calculated BSA does not directly correlate with the estimated BSA as we see differences up to 15%. This would change chemotherapy dosage by the same magnitude. Considering the narrow therapeutic index of these drugs, improving the accuracy of drug dosage can limit toxicity

Chemotherapy toxicity is associated with BSA-based dosing in small dogs. We show small dogs have the highest degree of variability in BSA.

The current K constant for dogs is 10.1. Using CT-calculated BSA, we found a K constant of 9.8.

Adding a linear parameter to the current equation, like height or length, may improve accuracy.