Calculation of body surface area using computed tomography-guided modeling in dogs

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Background

- Cancer chemotherapy dosage is calculated using an estimation of body surface area (BSA).
- The current formula to calculate BSA is $\frac{K \times W^{2/3}}{10{,}000}$ where K is the shape constant (10.1 for dogs) and W is the weight in grams.
- Chemotherapy toxicity in small dogs is associated with BSA-based dosing. Large dogs may be under-dosed, resulting in decreased efficacy.
- 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 in order to verify or modify the current BSA equation.
- The therapeutic margin between toxicity and efficacy is narrow for cancer chemotherapy. Improving the BSA equation can increase efficacy and decrease life-threatening sequelae.

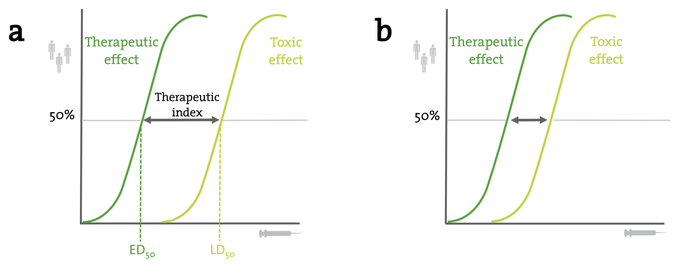

Figure 1 – Sample dose-response curves showing (**a**) a wide therapeutic index or (**b**) a narrow therapeutic index.

Methods

Full-body CT scans

- Previous full-body CT scans were used from animals requiring diagnostic imaging.
- Images were obtained using a helical CT (Toshiba Aquilion 64, Tustin, CA.).

Patient Contouring and Bolus

- 1-3 mm slices were transferred to XiO radiation treatment planning software (release 2.6, Elekta, Stockholm, Sweden).
- The patient was contoured using the contouring function, then edited in each 2-D plane.
- A 1 mm thick bolus was applied around each 2-D image.

Data Analysis

- Bolus values were exported to Excel 2013 for Windows (Microsoft Corp., Redmond, WA).
- BSA was calculated by adding the 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 cm² to m².

Results

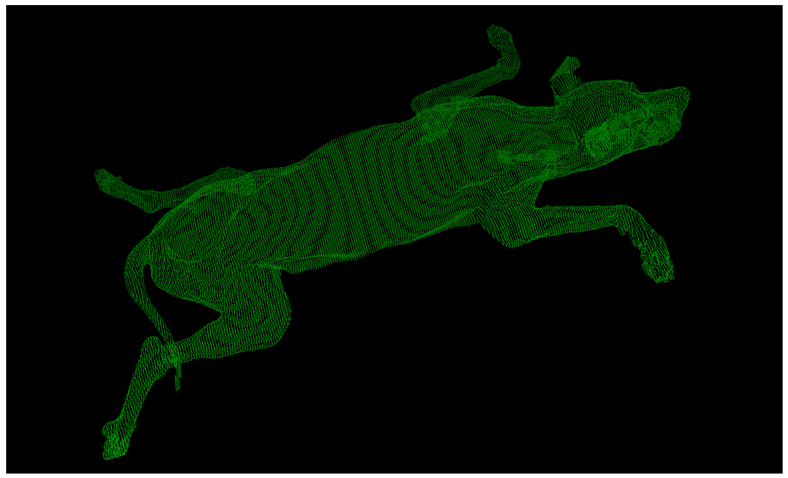

Figure 2 – 3-D reconstruction for confirmation of body outline.

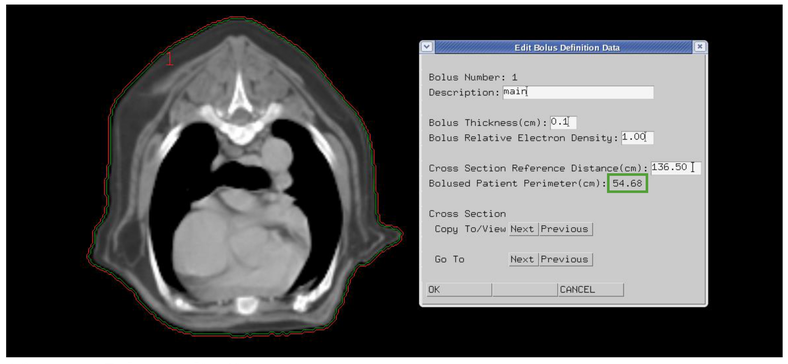

Figure 3 – Bolus application.

Weight (kg)	Size	Body Surface Area (m²) Estimated	CT	Percentage Difference	K Constant
3.60	Small	0.237	0.204	-13.92	8.7
6.00	Small	0.333	0.394	+16.78	11.9
11.36	Medium	0.511	0.525	+2.73	10.3
13.40*	Medium	0.570	0.521	-8.60	9.2
14.70*	Medium	0.606	0.505	-16.67	8.4
22.77	Medium	0.811	0.816	+0.62	10.1
30.50	Large	0.986	0.949	-3.75	9.7
40.00	Extra Large	1.181	1.110	-6.01	9.5

Table 1 – Values for BSA of 8 dogs estimated using the BSA equation and calculated via CT and radiation planning software. The percentage difference between the values was calculated as: percentage difference = 100–[(CT/estimated)X100]. The * denotes the same patient before (14.70 kg) and after (13.40 kg) amputation of the right forelimb. The average K value, obtained via the BSA equation, was 9.75.

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Conclusions

- We first evaluated the same scan using both 1 mm and 3 mm slices. The results returned a percentage difference of 0.2% (1 mm=0.522 and 3 mm=0.521). From this point, we continued using either 2 or 3 mm slices .
- Using the estimated and CT-calculated BSA values, drug dosages for common chemotherapy drugs were calculated. These variations in BSA can make a difference in the efficacy and toxicity of the drug.

Weight (kg)	Carboplatin (mg) Estimated	CT	Doxorubicin (mg) Estimated	CT	Vincristine (mg) Estimated	CT
3.60	63.99	55.08	0.24	0.20	0.17	0.14
6.00	89.91	106.38	0.33	0.39	0.23	0.26
11.36	137.97	141.75	0.51	0.52	0.36	0.38
13.40	163.62	136.62	0.61	0.51	0.40	0.36
14.70	153.90	140.67	0.57	0.52	0.42	0.35
22.77	218.97	220.59	24.33	24.51	0.57	0.57
30.50	295.80	284.70	29.58	28.47	0.69	0.66
40.00	354.30	333.00	35.43	33.30	0.83	0.78

Table 2 – Dosages for common chemotherapeutic drugs. Dosages were calculated according to the following: Carboplatin – 300 mg/m² ⩾25 kg, 270 mg/m² <25 kg; Doxorubicin – 30 mg/m² ⩾15 kg, 1 mg/m² <15 kg; Vincristine – 0.7 mg/m².

- We also found the CT-calculated BSA on a patient both before and after amputation of the right forelimb. However, we did not obtain our expected outcome due to the positioning of the animal. Prospectively, patients will be positioned in a way to facilitate calculation of BSA.
- Overall, the CT-calculated BSA does not directly correlate with the estimated BSA as we see differences up to about 17%. These changes are occurring in both directions, so changing the K constant alone may not be enough. In some instances, we see a close approximation, but the variation is not consistent. There may also be other patient-related factors for pharmacokinetics that are not related to body shape and size.

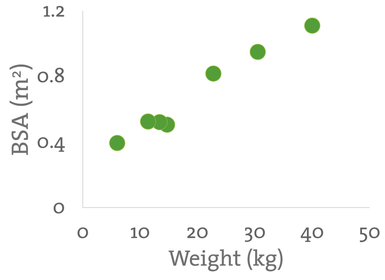

Figure 4- Plot of BSA and body weight. Each circle represents the results from one dog. R^2 goodness of fit was 0.9741.

Future Directions

- Continue adding retrospective CT scans and prospectively enroll dogs into this study, making sure to optimize positioning for determination of BSA.
- Apply this prospectively to dogs undergoing chemotherapy to see what parameters correlate best with chemotherapy toxicity.
- Obtain height and length measurements to see if adding another dimension to the current equation would increases its accuracy.
- Assess the affects of body composition on BSA and chemotherapy drug dosing.
- Perform this same study on cats of various sizes and body compositions.