Purpose: To assess the importance of tissue segmentation for Monte Carlo (MC) dose calculations with kilovoltage photon beams and to suggest a new segmentation method based on effective atomic number differences.

Methods: MC dose to 34 ICRU-44 tissues was calculated in a phantom irradiated by a number of kilovoltage beams using the EGSnrc/BEAMnrc and DOSXYZnrc codes. Photon beams currently used in small animal radiotherapy were studied: a microCT 120 kV beam, two 225 kV beams filtered with either 4 mm of Al or 0.5 mm of Cu, a heavily filtered 320 kV beam, and a 192Ir beam. MC dose was calculated for a five 120 kV beam treatment plan for a mouse with lung cancer. The microCT images were segmented using three different segmentation schemes – with 4 (the DOSXYZnrc default), 8, and 39 tissue types. The 4-tissue and 8-tissue segmentation schemes were based only on mass density differences. The new advanced 39-tissue segmentation scheme is based on the combination of both mass density differences and atomic number differences.

Results: Using our model we showed that mis-assignment of adipose to cartilage caused dose calculation differences of 36%, 24%, and 14% for the 120 kV beam and the 225 kV beams filtered with 4 mm Al and 0.5 mm Cu, respectively. A second order polynomial approximated well the absorbed dose to tissue as a function of the effective number for all beams. The small animal study showed that the doses to adipose and bone were overestimated by 30-50% when the 4-tissue segmentation was used compared to the 8-tissue and 39-tissue segmentation schemes. The dose to the lungs and bone were underestimated by 5-10% with the 39-tissue segmentation compared to the 8-tissue segmentation.

Conclusions: A new tissue segmentation method was proposed for a more accurate MC dose calculations with kilovoltage beams.