The viability of DCE-CT kinetic analysis in tumor vasculature imaging in veterinary medicine

Matthew D. La Fontaine

Under the supervision of Robert Jeraj

At the University of Wisconsin-Madison

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Abstract

Tumor vasculature imaging plays an important role in measuring tumor growth,[1-2] and metastasis formation,[3] which helps assess patient prognosis,[4] and guide therapeutic interventions.[5] Dynamic contrast-enhanced computed tomography (DCE-CT) is a non-invasive method for imaging tumor vasculature,[5] and has demonstrated potential for a variety of uses in oncology.[6-10] DCE-CT imaging has potential in veterinary medicine as CT machines are becoming prevalent and the dose from CT imaging is not as limiting due to the shorter lifespan of the animals.[11] However, in order to be useful in veterinary clinical oncology, DCE-CT imaging needs to provide quantitatively precise and accurate vasculature parameters. The overall goal of this work was to investigate the viability of DCE-CT kinetic analysis in tumor vasculature imaging in veterinary patients.

To assess the precision of kinetic parameters derived from DCE-CT imaging, we implemented kinetic models and characterized uncertainties. We examined many sources of uncertainty that impact the quantitative accuracy and precision of the kinetic parameters in veterinary scans, including factors originating from the CT scanner, the analysis, and the patient. We found that the kinetic parameters were sensitive to many sources of error leading to an overall high level of uncertainty. Several of the evaluated sources of uncertainty were scarcely researched prior to our investigation such as vessel selection, vessel segmentation, acquisition time, and patient-specific effects.

In order to validate the results of DCE-CT scans in veterinary patients, we compared DCE-CT kinetic parameters to kinetic parameters derived from FLT PET scans. While several studies investigated ROI comparisons, our investigation involved the more seldom applied voxel-wise comparisons. We found moderate agreement between the kinetic parameters from the two imaging modalities on the voxel level. However, kinetic parameter uncertainties on the voxel level strongly impacted the agreement between the modalities as the application of noise reduction techniques to kinetic analysis improved agreement between the imaging modalities.

In order to assess the added value of DCE-CT scans in multi-modality imaging in veterinary patients, we compared the kinetic parameters from DCE-CT kinetic analysis to pre-treatment PET tracer SUV uptake values as well as PET tracer response to radiation therapy. Three PET tracers were used to image glucose metabolism (FDG), cellular proliferation (FLT), and hypoxia (Cu-ATSM) of the tumor. Poor spatial agreement was found between tracer uptake patterns and voxel-based DCE-CT kinetic parameters, but good agreement was found between patients for DCE-CT kinetic parameter summary values and PET SUV measures. Similar correlations were observed between the response of the DCE-CT kinetic parameters to radiation therapy and the response of PET uptake values to radiation therapy for both spatial and whole-tumor analysis.

In conclusion, DCE-CT kinetic analysis requires further improvements in order to increase its utility in tumor vascular imaging for veterinary patients. DCE-CT kinetic parameters are sensitive to several sources of uncertainty. Current applications of DCE-CT kinetic analysis should attempt to minimize noise and use only whole tumor analysis, and not voxel-based analysis.

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