Personalized Dosimetry for Treatment of Hepatic Cellular Carcinoma using Multiphysics Simulations

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Treating liver cancer patients with transarterial radioembolization uses radioactive yttrium-90 microspheres injected in the hepatic bloodstream via a catheter. Quantification of the absorbed dose in the tumour and normal tissues pre and post treatment is important to optimize the efficacy yet lacks sufficient accuracy and precision. The dose distribution is needed to determine the dose-response and dose-toxicity relationships to mitigate or treat adverse effects. Additionally, radioembolization requires quick clinical decision-making at the time of the yttrium-90 microsphere injection, leading to challenges in implementing accurate and computationally inexpensive pre-treatment models.

We developed CFDose that incorporates clinical patient cone-beam Computed Tomography (CBCT) images and computational fluid dynamics techniques to predict the microsphere transport in the patient liver vasculature. Radiation dosimetry can then be performed from the predicted microsphere transport. Post-treatment Positron Emission Tomography (PET) imaging of the microspheres is used with Monte Carlo simulations to calculate the absorbed dose in individual liver segments.

One of the long-term goals of this work is to compare pre-and post-treatment simulations for treatment planning and evaluation for individual patients. This comparison requires different medical images modalities that often are not all available for a given patient, making it challenging to perform this task.

Preliminary results show similar discrepancies for pre-and post-treatment evaluation for two different patients and activities, when compared to the Medical Internal Radiation Dose (MIRD) formalism, where the absorbed dose for ^{90}Y is defined as $D=49.7\times A_0[MBq]/m[g]$. With CFDose, the calculated absorbed dose is 9.0% lower than that predicted by MIRD while the Monte Carlo absorbed dose is 8.8% lower. Due to patient scan variability, both methods could not be applied to the same patient, but each method shows small underestimations when compared to MIRD. These results build confidence that a close match between pre-and post-treatment evaluation can be ultimately obtained.

CF Dose: A personalized CFD Dosimetry

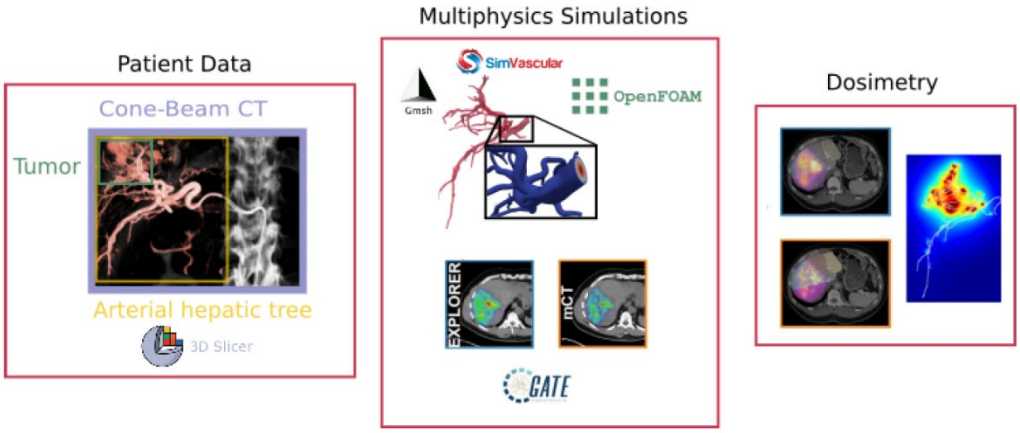

Figure 1:

Overview of the workflow for CFDose, beginning with patient data and ending with personalized dosimetry. In the left most panel, patient cone beam CT data is processed to extract the arterial tree. The center panel gives an overview of the tools used to combine CFD and Monte Carlo simulations. Finally, in the right most panel, the results are combined to give patient specific dosimetry.