Fast Finite Element Bioheat Solver for Cancer Treatment Lesion Predictions

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Bridging therapies are the most common cancerous treatment when surgical resection or organ transplantation is complex for even well experienced radiologists. Visualization of minimal invasive cancer treatment (MICT) is the choice for IRs to monitor the treatment online or decide the correct treatment beforehand. However, to visualize one has to solve at least three different coupled PDEs: (1) the Laplace equation for electric potential and then obtain the heat source term from electric potentials, (2) Penne's bioheat equation for temperature distribution and (3) a three state cell death model to identify dead cells. The total treatment of radiofrequency ablation (RFA) takes between 20 minutes and 1 hour during the clinical intervention procedure. Solving these coupled PDEs for a minimum of 1 million finite element mesh makes the simulation infeasible. To approximate (1), we have modeled and proposed an alternative method called point source model which completely omits to find the FE solution of the Laplace equation. However, solving (2) and (3) using FE is necessary. Using the distributed or cluster computing makes the simulation tool infeasible for the clinical treatment. Therefore, advanced heterogeneous computing using personal computers, incorporating the graphics processing unit (GPU) and the central processing unit (CPU), is proposed for the simulation. We developed a fast finite element bioheat solver to predict the lesion (a collection of dead cells) by doing most of the computational tasks in the GPU, while reserving the CPU for concurrent tasks such as lesion extraction based on the heat deposition at each finite element node. Our solver produces the simulated lesion within 3 to 5 minutes for treatment duration of 26 minutes to 1 hour. Since, the solver accommodates patient- and device-specific parameters, the surface deviation between the treatment outcome and simulated outcome is below 3mm. As per our multi-centre retrospective study, our solver predicted more accurate lesions for more than 90% of the cases and hence it is suitable for the clinical environment.