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Model-based percutaneous thermal ablation planning – retrospective analysis on a clinical dataset

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Abstract— **A biophysical model is envisioned to assist the radiologist in the percutaneous thermal ablation procedure of liver tumors, by predicting in real time the thermal deposition from a microwave (MW) applicator. A retrospective analysis on a cohort of 21 patients shows an improvement of model prediction compared to manufacturer data and highlights the cooling effect from vasculature on the thermal dose.**

Clinical Relevance— **The biophysical model is integrated in the imaging platform, in addition to the segmentation and automatic registration tools. This provides a solution to tackle multiple contrast enhanced (CE) scans for vasculature segmentation, real time adjustment of the applicator in 3D and visualization of the predicted ablation overlaid on the CT images, making it accessible to less experienced radiologists.**

I. INTRODUCTION

Percutaneous thermal ablation relies on heat deposition at the tip of an applicator, locally inserted towards a targeted hepatic lesion [1]. Compared to open surgery, this minimally invasive technique reduces side effects, recovery time and improves quality of life of patients. Nevertheless, planning the optimal position followed by positioning the applicator in the target volume remains challenging. Current clinical practice, based on manufacturer data and operator experience, can lead to inter-operator variability and thus local recurrences. To assist the radiologist and simplify the procedure, a biophysical model is envisioned within the imaging platform, to predict in real time the thermal deposition from a MW applicator.

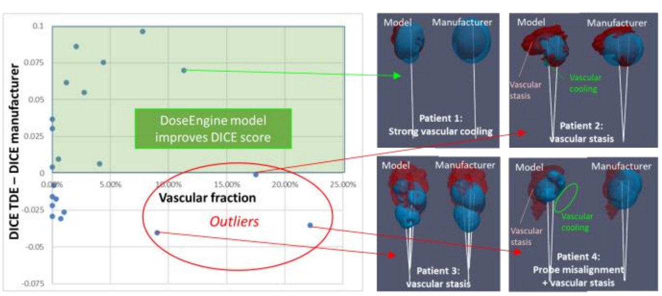

Figure 1. DICE coefficient difference between biophyiscal model and manufacturer data plotted as a function of the vascular fraction.

II. METHODS

The main focus of this work is a retrospective analysis between the actual ablation ground truth (segmented manually by an experienced radiologist using the CE post ablative scan) and the model prediction. Liver and vasculature are automatically segmented from CE images. The applicator is positioned manually on the last pre-ablation scan using an interactive tool. Automatic registration is performed between those scans to compensate for patient motion artefacts. The biophysical model is described in a separate submission. It relies on the transient bioheat equation where a non-uniform cooling heat sink is applied in the segmented vasculature. Performance metrics (DICE coefficient, ablation volume, Hausdorff distance) are reported to the radiologist. Vasculature effect is quantified as a fraction of its intersection volume with respect to the manufacturer total volume.

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III. RESULTS

Results show improved prediction with the model compared to manufacturer data, with a DICE coefficient 0.1 higher for most of the patients (Figure 1), especially with a large vascular fraction (patient 1). An analysis of the outliers (patients 2-4) shows some limitations of the retrospective analysis. Multiple ablations performed in highly vascularized areas leads to vascular stasis and thus in an overestimation of the ground truth. In these cases, although the perfusion is well captured in the model, the manufacturer data matches better to the ground truth because it tends to overestimate the ablation zone and thus covers partially the vascular stasis area. From a clinical perspective, a true estimation of the thermal deposition is crucial to cover the lesion, meaning that the predictions from the model (excluding vascular stasis) are more reliable. Additional challenges arise in this integrated workflow, e.g. misalignment of the probe due to the registration error, incomplete vasculature segmentation around the probe due to a low amount of contrast. The latter can be mitigated using a better contrast dosage and phase timing.

IV. DISCUSSION & CONCLUSION

The analysis of our biophysical model integrated in a clinical imaging platform on 21 retrospective clinical cases shows superiority compared to manufacturer data and highlights caveats that must be considered in future studies. It also demonstrates the importance of using the appropriate contrast phase selection and dosage for an accurate vasculature segmentation. At the end, this model can assist the radiologist with the thermal ablation and thus help in the standardization of the procedure for less experienced users.

REFERENCES

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