

IMPACT

Image-based Multi-scale Physiological Planning for Ablation Cancer Treatment

IMPACT develops an intervention planning system for Radiofrequency Ablation of malignant liver tumours accounting for patient specific physiological factors. Validation is performed at multiple levels through comparison of simulation and treatment results gathered in animal studies and during patient treatment.

Objectives of the Project

Radiofrequency Ablation (RFA) is a minimally invasive form to treat cancer without open surgery, by placing a needle inside the malignancy and destroying it through intensive heating. Though the advantages of this approach are obvious, the intervention is currently hard to plan, almost impossible to monitor or assess, and therefore is not the first choice for treatment.

IMPACT will develop a physiological model of the liver and simulate the RFA intervention's result, accounting for patient specific physiological factors.

- Closing gaps in the understanding of particular aspects of the RFA treatment by multi-scale studies on cells and animals
- Embedding microscopic findings into a macroscopic model for heat conductivity by liver tissues
- Extending the long-established bio-heat equation to incorporate multiple scales
- Cross checking validity for human physiology by comparison against images from ongoing patient treatments
- Visual comparison of simulation and treatment results gathered in animal studies and during patient treatment
- Validating results at multiple levels and with a user-centred software to guarantee best suitability of the model for clinical practice.

Project Description

Predicting the intervention result physiologically correct demands an accurate and verified patient specific mathematical model. A bottleneck on the way towards the patient specific planning tool is our so far limited understanding of processes during tissue heating and, ultimately, tissue death as the result of that heating. IMPACT aims at opening this bottleneck by generating new

insight into physiological processes and biochemical reactions in the context of tissue heating. Heating has a strong influence on perfusion of tissue, reaction

IMPACT will create the Intervention Planning System (IPS) as a clinically relevant application.

rates in chemical processes, as well as the organ's and overall system's health condition. Local hyperthermia can be used to kill a limited volume of cells while keeping surrounding parts vital and healthy. Many different treatment strategies rely on this approach.

IMPACT attacks the challenge of predicting the RFA process by **computational modelling and simulation**. The long existing bio-heat equation needs to be revised. Cellular behaviour during heating and cell death (microscopic

To model the RFA process properly and in a verified manner, its mathematical description has to be validated against experimental results.

level) determine the final (macroscopic) shape of the necrosis zone significantly, but these processes have not yet been adequately modelled. Furthermore, constants in the presently used equation are in fact not universal but **patient specific parameters**. The necessary **multi-scale simulation** approach leads to numerically solving partial differential equations in 3D using the finite element method. Results and variations will be handled in a flexible solution space to allow **interactive planning and visualization** of treatment results. All modifications as well

Augmented reality training simulator raises acceptance for the Intervention Planning System.

as simulation results will be **validated in phantom and animal experiments and cross compared to ongoing clinical patient treatment**. Accurate reconstruction of identifiable and physiologically meaningful 3D anatomical structures from images demands new image processing tools. A workflow oriented approach guarantees its suitability to clinical practice.

SCENARIO

A patient diagnosed with tumours in the liver enters the hospital to be treated by RFA. Several radiological images are taken from him as preparation for the intervention. A patient specific model is created and prepared for interactive simulation of results. Now the radiologist in charge uses the model simulations to predict the intervention results. Based on personal assessment of the situation the radiologist selects a good needle position and ablation protocol. The model allows watching the intervention result prior to the treatment while testing a variety of alternative approaches before taking final decision on the best intervention plan. The patient receives the best possible treatment for his specific case and leaves the hospital two days later with minimal side effects on his life.

Furthermore, an **augmented reality training simulator** will teach surgeons optimal RFA application, before they start using this treatment. IMPPACT will bring RFA from its last resort status up to the treatment of choice for hepatic cellular carcinomas and liver metastases. In creating the training simulator a methodology for identifying the key features in every simulation step and aspect will be developed and thereby push research on medical augmented reality training simulators far forwards.

Expected Results & Impacts

IMPPACT will be modelling a physiological organ including the metabolism and patient specific tissue properties. This alone is a huge step forward as compared to the state-of-the-art intervention planning systems that do not address this issue.

The IPS will allow prediction of treatment results on a patient specific base. It will therefore bring down the risk of local recurrences and eliminate the nowadays so common repeated treatments of the same tumour, making RFA an as effective treatment as resection.

At the same time the IPS will make RFA treatment much safer. By reliably predicting tissue heating it will warn of possible damage to surrounding organs in advance and allows choosing a safe needle position and path.

The greatest impact will be achieved by installing the created application in many hospitals in Europe. To be able to directly use the IPS in clinical practice medical personnel in those hospitals needs to be trained in using it. The augmented reality training simulator provides an excellent opportunity as it trains surgeons directly with the IPS.

All developed software will be open source and run with common hospital equipment. Its deployment to virtually every hospital in Europe is solely a question of using a deployment infrastructure.



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- NUMA Engineering Services Ltd (Ireland)

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KEYWORDS

Medical visual computing, Patient-specific modelling, Multi-scale validation, Interactive simulation