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Development of a realistic phantom of a mouse's head : application to photoacoustic temperature monitoring during photothermal therapy

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Abstract: We developed a numerical phantom of a mouse's head where we performed photothermal therapy on a tumor. Nanoparticles are numerically added and their effects are studied. The medium's temperature was monitored using the photoacoustic technique. © 2021 The Author(s)

PhotoThermal Therapy (PTT) refers to the use of optical radiation, usually near infrared light, in order to treat diverse medical conditions, most commonly, cancer. Light received by the tissues is absorbed and converted into heat leading to rises in temperatures, which in turn lead to the death of the cells and their thermal ablation. In PTT, optical absorbers are commonly used in order to increase the efficiency of the treatment and target specific area. Usually, metallic nanoparticles (NPs) are used as they show strong tunable absorption.

In the recent years, PTT gained an important popularity due to its localized and non invasive treatment advantage. With its constant improvement, new efficient numerical tools are developed for the simulation of the therapy in order to confront simulated to experimental results. Following these approaches and with the aim of enlightening experimental results, we developed a numerical phantom of a mouse's head where PTT was performed. The phantom was built using atlas obtained with different imaging methods and available online [1–4] to numerically recreate the more precisely possible the morphology of the mouse's head. Moreover, a particular attention has been paid to the physical parameters needed for the numerical simulations : a thorough literature review was performed to design this highly realistic phantom. The case of a tumorous brain was considered and compared to the reference case of a healthy brain. The phantom is presented in Fig. 1, and the position of the tumor is indicated. Additionally, NPs were added numerically in the brain : their effect was simulated by a local increase of the ab-

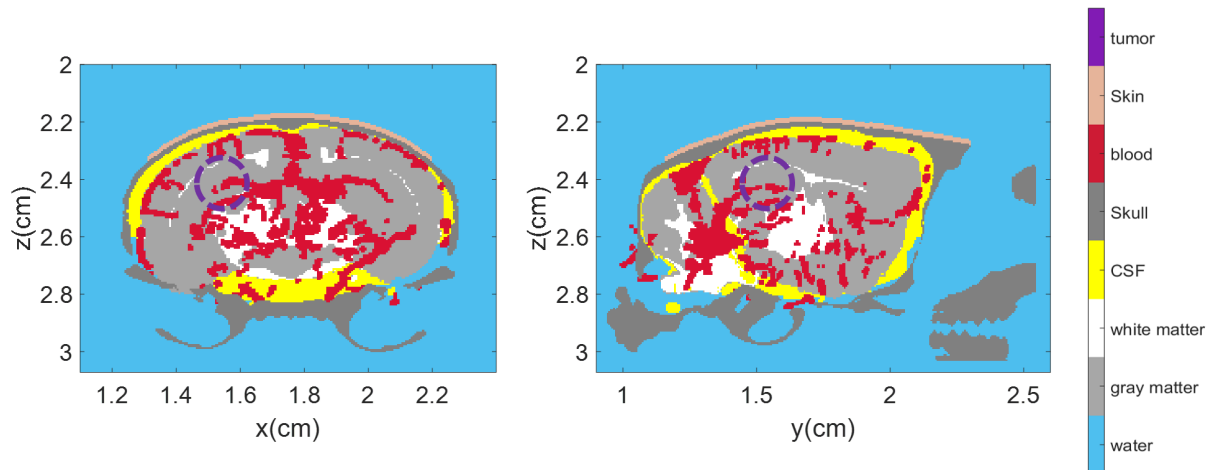


Fig. 1. Phantom of a mouse's head : 2D sagittal and cortical view of the phantom. Tumor's contour is indicated by the dashed purple line.

sorption properties. Different cases were considered in the form of different local increases. The results obtained were compared to understand the effect of the tumor and the NPs on the therapy.

During the therapy, a real-time temperature monitoring method is needed in order to control the thermal damages caused to the tumor and its surroundings. For such purpose, the PhotoAcoustic (PA) technique has been

shown to be a good candidate, as it allows for in depth, non invasive real-time temperature monitoring. [5–7]. As temperature change in the phantom, the PA signal undergoes variations in amplitude. This dependency was implemented in the phantom. It is therefore possible to link these variations in amplitude to the increase of temperature.

To numerically simulate the therapy, the heat generated by the light source has been calculated using the Monte Carlo method. Heat diffusion simulations were then performed on the phantom by solving Penne’s bioheat equation [8]. Finally, PA simulations were conducted during the PTT, and variations in the signals received were studied and linked to temperature in the phantom.

With our numerical study, we manage to :

- Model the temperature evolution in the phantom and the tumor.
- Quantify the thermal damages caused to the tumor and the surrounding healthy tissues.
- Investigate the feasibility of accurate temperature monitoring through the use of the PA technique.

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