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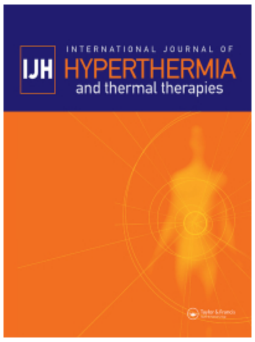

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INTRODUCTION

Introduction to computational modeling in hyperthermia

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Over the past two decades, computational modeling has gained a prominent role in hyperthermia research and its role for guiding treatments is expanding. Computational modeling serves e.g., to design new applicators, in silico testing of novel treatment approaches and providing insight in treatment safety. Hyperthermia treatment modeling and optimization (HTM&O), also known as hyperthermia treatment planning (HTP), is the process in which the multidisciplinary hyperthermia team defines the optimal treatment plan for a specific cancer patient using the available hyperthermia treatment resources. HTM&O includes computational modeling approaches for pretreatment HTP and online treatment guidance.

This special issue connects to the ESHO Grand Challenge,[1] which was initiated to reflect the prominence of HTM&O computational tools, not only for HTP but also for heating device design and optimization of treatment strategies. The ESHO Grand Challenge is a direct response to the fact that, while HTM&O is gaining broader traction, there is a lack of standardized computational practices and verification or performance benchmarks. Therefore, a group of experts in electromagnetic and focused ultrasound hyperthermia computational modeling, and its clinical application, jointly developed such modeling benchmarks [1], including the new Erasmus Virtual Patient Repository (EVPR) [2]. In this special issue, leading experts exploit, discuss or advance the various aspects of HTM&O, in relation to the new benchmarks.

As an initial step, the importance of the benchmarks and EVPR was demonstrated by Zanoli et al., who proposed and benchmarked a novel SAR-based optimization cost function [3]. Androulakis et al. analyzed the suitability of the EVPR using 22 anatomically and pathologically diverse breast cancer patients. In a next step, Curto et al. used such models for the design of an MR compatible hyperthermia applicator for the treatment of intact breast cancer [4]. Bottauscio et al. used computational modeling to evaluate the safety of magnetic hyperthermia applied to patients with pancreatic ductal adenocarcinoma wearing metallic biliary stents [5].

Apart from conventional applications, this issue also specifically emphasizes the use of HTM&O for adaptive treatment approaches both with and without feedback from MR thermometry, as well as rather novel modeling approaches in drug delivery. Computational modeling was shown to support magnetic resonance (MR) thermometry, e.g., in case of (air-)motion artifacts. Nouwens et al. demonstrated a reduced mean absolute error when combining thermal and magnetic susceptibility modeling for model-based correction of the temperature measurement [6]. The information from MR imaging can also be used to adapt HTP to the patient in treatment position. The benefit of such an approach was studied by VilasBoas-Ribeiro et al. [7]. Ramajayam et al. combined *in vitro* experiments with a computer modeling to evaluate the potential efficacy of various investigative drugs preceding encapsulation in thermosensitive liposomes for targeted drug delivery [8]. Targeted drug delivery was also investigated by Gray et al., who found that respiratory motion during ultrasound-mediated hyperthermia is the most important confounder for simulation accuracy, followed by the acoustic properties of the pancreas and the shape of the abdominal wall [9].

Our knowledge of tissue properties and their physiological dynamics is currently limited. As a consequence, HTP carries uncertainties that may lead to sub-optimal delivery of the hyperthermia treatment. Vaupel et al. demonstrated that water content imaging may reduce the uncertainties since they found a strong correlation between specific heat capacity and water content in human tissues [10]. Sebek et al. studied such image-based computer modeling assessment of microwave ablation for treatment of adrenal tumors [11]. In addition, Kok et al. reviewed the status of biological modeling in thermo-radiotherapy to predict and optimize hyperthermic effects in combined treatments with radiotherapy [12].

In summary, despite of the enhanced availability of computational tools, different simulation approaches, tissue and modeling uncertainties, translation issues and various model parameter settings have led to a situation in which comparing the benefits of the various HTM&O strategies is nearly impossible. Without benchmarks that define a common ground, progress in the thermal therapy fields will be

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severely compromised. Hence, we hope that this special issue, combined with the new benchmarks [1] and representative patient models [2], will inspire and support computational modeling based innovations in thermal therapy, leading to faster improvement of treatment effectiveness.

Note

1. https://www.esho.info/eshograndchallenge/

Disclosure statement

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