Simulation of Mass Transport during Intraperitoneal Chemotherapy: a Parametrical Model of Single Tumor Nodules

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OBJECTIVES

Patients with peritoneal carcinomatosis suffer from a widespread metastatic growth of tumor nodules in the peritoneal cavity. Although Intraperitoneal (IP) chemotherapy allows for higher intratumor concentrations of the cytotoxic agent compared to intravenous administration, actual application of IP chemotherapy is limited due to poor drug penetration (typically a few millimeters) in the tumor tissue. It is thus essential to better understand the drug transport during IP chemotherapy.

METHODS

A 3D computational fluid dynamics model of a tumor nodule with necrotic core was created in Comsol® (COMSOL, Inc., Burlington, USA) describing the drug transport occurring during IP chemotherapy, including convective/diffusive/reactive drug transport in two tumor geometries (a spherical baseline model with radius $r_{sphere,large}$=1 cm/$r_{sphere,small}$=2 mm and $r_{necrotic,large}$=5 mm/$r_{necrotic,large}$=1 mm). To assess the efficiency of drug administration, a penetration depth (PD) was defined as the percentage of the total radius in which the drug concentration resulted to be over 6.6E-3 mol/m^3. These baseline models were subsequently adapted to evaluate the effect of therapy-related parameters (different drugs, vascular properties etc.) on drug penetration.

RESULTS

A large differences in PD (PD; % of total radius) were found in the baseline cases for the two different scales ($PD_{sphere,large}$= 4.04%; $PD_{sphere,small}$=20.82%).Vascular normalization therapy yielded different outcomes ($\Delta PD_{sphere,large}$+2.95%; $\Delta PD_{sphere,small}$ +17.95%). Both cases showed less penetration when paclitaxel was used as opposed to cisplatin. This effect was more pronounced in the smaller geometry ($\Delta PD_{sphere,large}$ =-1.91%; $\Delta PD_{sphere,small}$ =-10.25%).

CONCLUSIONS

The model is able to predict drug penetration depth for different sets of IP chemotherapy-related parameters, which may lead to optimization of drug transport during IP chemotherapy.