Monitoring tumor state from thermal images in animal and human models. 2015

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Abstract

PURPOSE:
Thermography is a potentially useful method for tumor progress monitoring since it is noninvasive, nonradiative, low-cost, and rapid. Perfusion and metabolism are dominant factors for determining tumor temperature difference and are also correlated to the tumor's growth rate. Therefore, estimating them from the tumor thermal image can be a very useful tumor monitoring method, since thermal changes occur before physical changes. The goal of this work was to study the effect of tumor state on the thermal image in different tumor types, using simulations and measurements.

METHODS:
Simulated tumor models, representing flat and extruding tumors, typical to transplantable and natural tumors, respectively, were simulated and the effects of tumor metabolism and perfusion on the temperature difference were analyzed. Data regarding tumor size and measured temperature differences were obtained from the literature, discussing five types of transplantable tumors in mice and rats. The growth rates of all tumors were calculated by fitting tumor size measurements to a tumor growth model and were used as an indicator to tumor aggressiveness. Tumor temperature difference was calculated by taking the effect of its extruding shape into account, according to a previously published method. Tumor state was estimated from the normalized temperature differences using simulations and compared to the calculated aggressiveness rates. Computational models of human breast cancers, both in round and flat breast models, were recreated using a finite-element-method heat transfer simulation. Tumor size and state were simulated according to the results obtained from the animal tumor analysis, representing two different tumor aggressiveness levels. The calculated temperature difference as a function of tumor size was calculated for each test case.

RESULTS:
Perfusion was shown to be highly dominant in determining the tumor's temperature difference. Since both metabolism and perfusion were shown to have a linear effect on the temperature difference, a conversion value was defined between them. The analysis of the animal experimental results showed correlations between tumor aggressiveness and the following factors: the normalized temperature difference, the estimated tumor state, and the temperature difference change rate. The simulated human breast cancer models analysis showed highly varying temperature differences between the simulated models. Although for each model there is a clear difference between the temperature differences of the test cases simulated, the large differences between the results might make tumor state estimation difficult. However, reviewing the gradient of the tumor temperature change as a function of tumor size showed that the ratio between the gradients of both test cases was similar for all models. Therefore, the effect of model errors and differences in the simulated tissue structure and properties and the environmental conditions between the different models, can be mitigated. This pattern may be used to estimate tumor state in in vivo experiments.

CONCLUSIONS:
Continuous monitoring of tumor temperature difference produces valuable information on tumor state and aggressiveness that can be used both in the clinic and in the laboratory. Monitoring can be either performed on a single image, or continuous on multiple images, revealing changes in tumor state.

Web link: http://www.ncbi.nlm.nih.gov/pubmed/25735285