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Modeling of the temperature field of a tumor tissue loaded by magnetic nanoparticles

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Mohammed Nassim Bensenane, Assia Rachida Senoudi

Université Abou Bekr Belkaid, faculté des sciences, Département de physique, Tlemcen, Algérie

bensenane83@gmail.com

Abstract

Background: Magnetic hyperthermia is a recent therapy used to treat cancer. It is based on the heating of magnetic nanoparticles under the effect of an alternating magnetic field. A mathematical study was considered the effect of heating magnetic nanoparticles to obtain an increase in the desired temperature while causing minimal damage to surrounding healthy tissue. We investigated the thermal response of different materials. An analytical resolution is proposed to solve the bio-heat transfer problem in a two-zone tissue in spherical geometry with blood perfusion and metabolism. Bio-heat equation is used to predict the temperature rise in terms of characteristics of the different magnetic nanoparticles (MNPs), applied magnetic field, and size of the tissue.

Methods: The tumor is selectively loaded with magnetic nanoparticles of which are inside the healthy tissue, which does not contain nanoparticles. Under application of the magnetic field, the tumor will experience a rapid increase in temperature, which causes necrosis of the latter while healthy tissue remains safe.

Results: Results of the thermal response of three ferro-fluid materials (fcc Fe Pt), magnetite and maghemite (volume fraction of MNPs $p = 0.0001$), on the tumor (size r =1[cm]) under application of alternating magnetic field (the strength and frequency of applied AC magnetic field H=10 [kA/m] and f=300 [kHz]) show an increase in temperature at the center, which vary from one material to another. It reaches 51°C for (fcc FePt); for magnetite and maghemite, it reaches 43°C. The simulations show that these nanoparticles provide the necessary power to conduct treatment with hyperthermia. The different parameters show that they have an influence on the temperature we observed, ranging from 45°C up to 51°C for volume fraction of MNPs ˆ = 0.00006, 0.00008, 0.0001. The strength of applied AC magnetic field varies as H= 5, 10, 15(kA/m) and shows significant variation for the temperature ranging between 42°C and 60°C. For the frequency of applied AC magnetic field varied as f=150,300, 450(kHz), the temperature varies between 44°C and 54°C. Finally, the effects of tumor size are considered, the temperature with parameters of (fcc FePt) MNPs, p=0.0001, H=10 (kA/m), and f=300 (kHz) at the center and at the interface of the tumor for a size of 10 mm radius is 51°C and 48°C, respectively. For a tumor of 5 mm radius, we note that the temperature decreases at 49°C and 47°C, which is due to the effect of blood perfusion.

Conclusion: Theoretical evaluation of nanoparticles as warming agents for magnetic hyperthermia is carried out by combining the heat generating model and bio-heat transfer equation. Accordingly, (fcc FePt) MNPs were found to have a heat capacity greater than that of other MNPs such as magnetite. This study shows that each item contributes to a significant change in temperature, which causes us to determine the best to achieve optimal treatment. This therapy proves to be promoted with its ability to eliminate tumor tissue while preserving healthy tissue.

Keywords: *Bio-heat transfer equation, Cancer treatment, Hyperthermia, Nanoparticle*

1. Declaration of conflicts

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2. Authors' biography

No Biography

3. References

No references