Electromagnetic Snare

(Radio frequency radiation-induced hyperthermia using Si nanoparticle-based sensitizers for mild cancer therapy)

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Introduction

Cancer remains a major threat to mankind, despite significant progress in the past decade in understanding, treating and preventing the disease. Since about 40% of found tumors are not resectable, they are usually treated by relatively "heavy" chemotherapy methods. For some cancers, such as hepatocellular carcinoma, hyperthermic therapy using radiofrequency (RF) is an option when resection is not feasible [1].

The RF ablation method results in successful partial necrosis of tumor and can be significantly enhanced by using sensitizers, or properly designed absorbing agents, which are targeted into a tumor area (actively or passively), accumulate in it, and then absorb main RF radiation power to heat cancer cells and thus cause their selective destruction [2].

However, there are major concerns in using Au NPs and carbon nanotubes for the hyperthermia therapy, gold is not a biodegradable material, despite its good biocompatibility, and the injection of Au NPs in vivo can cause their long-term accumulation in the body with unclear consequences [3].

However, Si NPs have much weaker electrical conductivity of compared to Au-based counterparts, they manifest similar or better heating rate. Moreover, Si NPs are not only biocompatible but also biodegradable as in biological tissue and excreted naturally from the body through the urine [1

Aim of Work

The work aimed to test two different types of Si-based nanostructures and demonstrate which type is more efficient in the inhibition of the cancer.

Materials & Methods

Materials

Two different types of Si-based nanoparticles are prepared . The first type is produced by mechanical milling of electrochemically-prepared porous silicon. This method of fabrication is characterized as a fast and low cost of a large quantity of these NPs, however, the surface of the NPs should be cleaned from residual contaminants after the production.

The second type of Si-based NPs is prepared by methods of femtosecond laser ablation in deionized water. NPs produced by this method is free of any contaminants and toxic byproducts.

Methods

The time dependence of freshly prepared Si-NPs and La-Si Nps suspensions as a function of temperature growth was measure in comparison to the ionized water. Moreover, the dependence of the heating rate of different types of NPs on the intensity of RF radiation were measured.

The assessment of efficiency of RF radiation-induced treatment in biological models was carried out in vivo on the hyperthermia-based treatment of cancer tumors using small animal model (Fig.1).

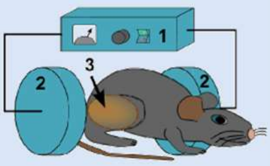

Fig.1: Schematic diagram of the biological model.
1. RF generator,
2. electrodes,
3. the targeted tumor

the inhibition of tumor growth was calculated using the following formula:

$$Inhibition = \left(1 - \frac{V}{V_o}\right).100\%$$

where V and V_o are the averaged tumor volumes for the experimental and reference groups of mice, respectively.

Results

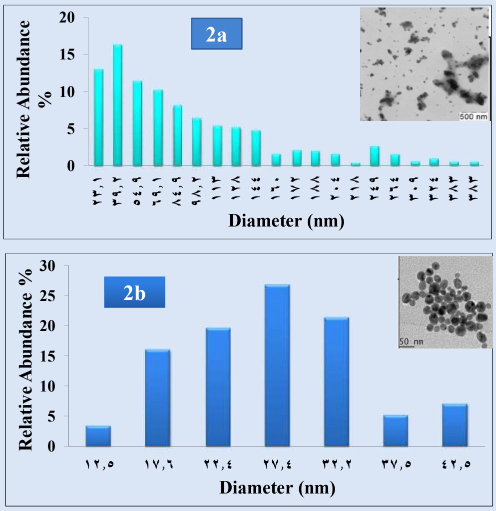

Fig.2: TEM image and corresponding size distribution for both NPs Suspension Porous Si (2a) and Laser ablation Si (2b) respectively

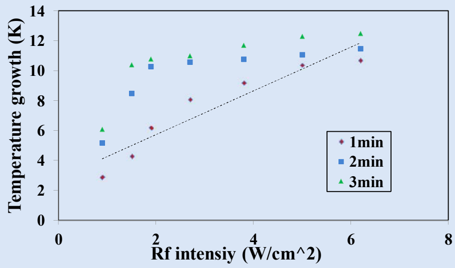

Fig.3: The temperature growth of porous Si NPs suspension as a function of RF intensity at different times

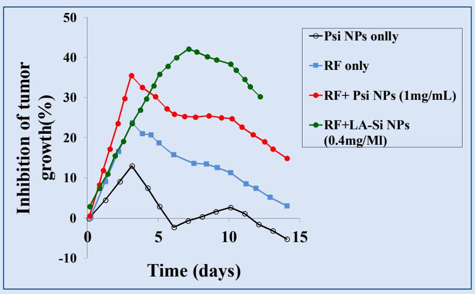

Fig.4: The inhibition percent of the tumor growth as a function of days at different setup

Discussion and Conclusion

- The electrically conductive nanoparticles can produce Joule heating through the RF-induced generation of local electrical currents over the NP volume resulting in heating of cancer cells which leads to a selective destruction (Fig. 5).

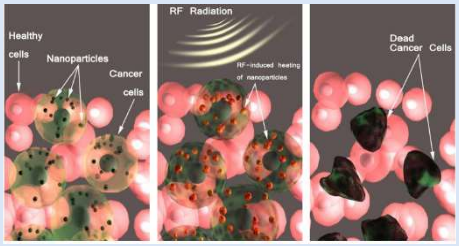

Fig. 5: Schematic representation of Radio frequency (RF) radiation-induced hyperthermia using RF-absorbing Si nanoparticle-based sensitizers

- The electrochemically-prepared PSi NPs have a wide dispersion in size and shape: the size distribution contains a broad spectrum with the peak value at about 50 nm and a considerable portion of larger (several hundreds of nm) NPs, however, the laser-ablated Si NPs (LA-Si NPs) have nearly ideal round shape with a much smaller mean size (25–30 nm) and a low size dispersion (Fig.2a&b).
- The heating of NPs solutions can be characterized by considering the Joule's heat dissipation.
- According to the model (Fig. 1), the Joule heating is due to local electrical currents around the NPs rather than to currents over the NPs volume. In the electric field of RF radiation the NP/ solution interface is rapidly polarized at the time scale of the order of 10^{-12}–10^{-14} sec and then an electrical double layer surrounding the NPs is formed.
- The combined action of PSi NPs and RF excitation could drastically amplify the effect leading to a much stronger inhibition of the tumor growth.
- The results revealed that Si-based nanoparticles can serve as efficient sensitizers for tasks of RF-induced cancer therapy, resulting not only in the inhibition of the tumor growth, but also in its elimination. This can be explained by local hyperthermia-based destruction of cancer cells due to the RF-induced heating sensitized by NPs.
- The greatest advantage is the PSi based NPs is excreted from the body through kidney not liver resulting in negligible side effects.

References

[1] Tamarov K.P., Osminkina L.A., Zinovyev S.V., et al., 2014. Radio frequency radiation-induced hyperthermia using Si nanoparticle-based sensitizers for mild cancer therapy; Scientific reports, 4:7043.

[2] Glazer E.S., and Curley S.A., 2011. Non-invasive radiofrequency ablation of malignancies mediated by quantum dots, gold nanoparticles and carbon nanotubes; Ther Deliv.,