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Investigating the potential benefits of using nanoparticle contrast agents to enhance OCT images

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Abstract

The OCT imaging technology, with its affordability, convenience of use, and excellent resolution, has drawn the interest of numerous medical imaging experts. However, a significant issue it faces is the imaging depth constraint. Numerous approaches, including different forms of optical clearing, have been proposed in studies to address this problem. Additionally, one way to address this issue that have been employed in OCT imaging for roughly two decades is the use of contrast agents deep inside the tissue with the goal of enhancing the reflected light from the tissue and improving the quality of OCT images. Despite some limitation of nanoparticles such as toxicity, because of their substantial refractive index difference from the background tissue, the nanoparticles utilized for this purpose are injected deep into the tissue, increasing the amount of backscattering that contributes to the OCT image's contrast. Various forms of nanoparticles can now be used in OCT imaging because to advancements in nanoparticle fabrication techniques. To get the greatest results, it is also essential to optimize the properties of the nanoparticles that are used. In the current work, various kinds of nanoparticles were injected into the chicken breast tissues, and OCT images were obtained at various intervals. The images contrast and nanoparticles diffusion time are compared. The lengthy duration of nanoparticle diffusion in tissues presents one of the difficulties in their application. The use of ultrasound modules in this study has accelerated the distribution of nanoparticles within the tissue, hence decreasing the time required for the contrast agent to be effective on the OCT images by about two times. Also, the OCT images contrast in the presence of nanoparticles shows an increase from 40 to 200% in different depths. The current study's findings can offer a practical way to shorten the time it takes for contrast agents to distribute throughout tissue, and by offering ideal contrast agent specifications, they can also significantly enhance the quality of OCT images that include contrast agents.

Material and methods

1- Three different kinds of nanoparticles were purchased from the XCHIM company: nanospheres, nanorods, and nanotriangles (Figure 1). Nanospheres and nanorods have been generated by chemical processes, while nanotriangles have been produced utilizing the protein-mediated auto reduction of gold salts [1, 2].

2- Using a slicer, chicken breast tissue was chopped into 2mm × 20mm × 45mm pieces.

3- The experimental setup schematic shows that in an aqueous environment, nanoparticles are injected into the tissue of the chicken breast. To ascertain the rate at which nanoparticles diffuse throughout the tissue, OCT images are acquired from a different portion of the tissue. OCT scans are performed 30, and 60 minutes following the nanoparticle injection (Figure 2).

4- The parameter of contrast to noise ratio (CNR) in OCT images is defined as follows [3]:

$$\mathrm{CNR} = \frac{1}{M}\sum_{m=1}^{M}\frac{(\mu_m - \mu_b)}{\sigma_m^2 + \sigma_b^2}$$

where μ_m and σ_m in CNR represent the mean and standard deviation of the mth region of interest, respectively, and μ_b and σ_b are the mean and standard deviation of the background noise region, respectively.

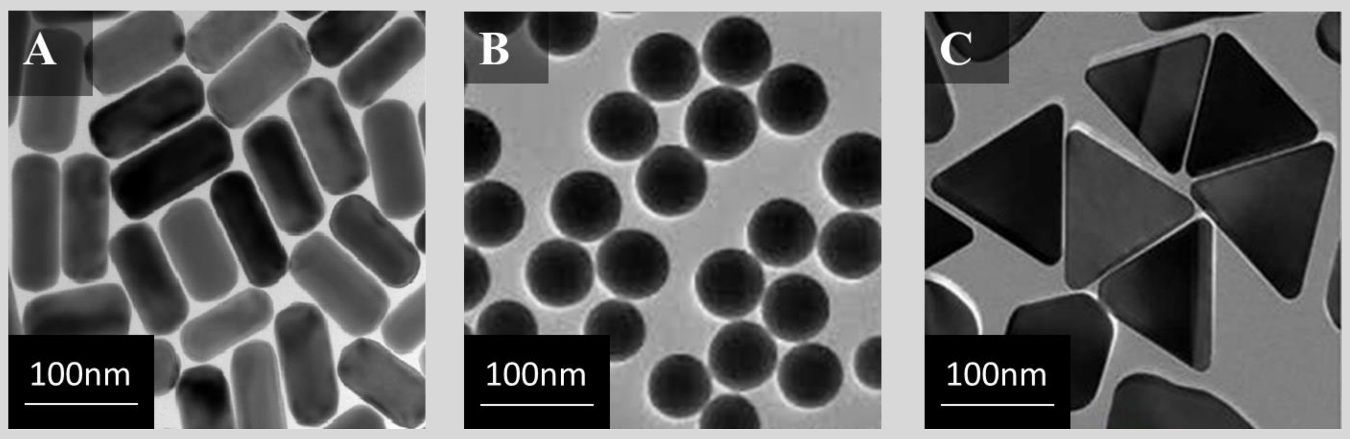

Figure 1- Nanoparticles TEM image: (A) nanorods, (B) nanospheres and (C) nanotriangles.

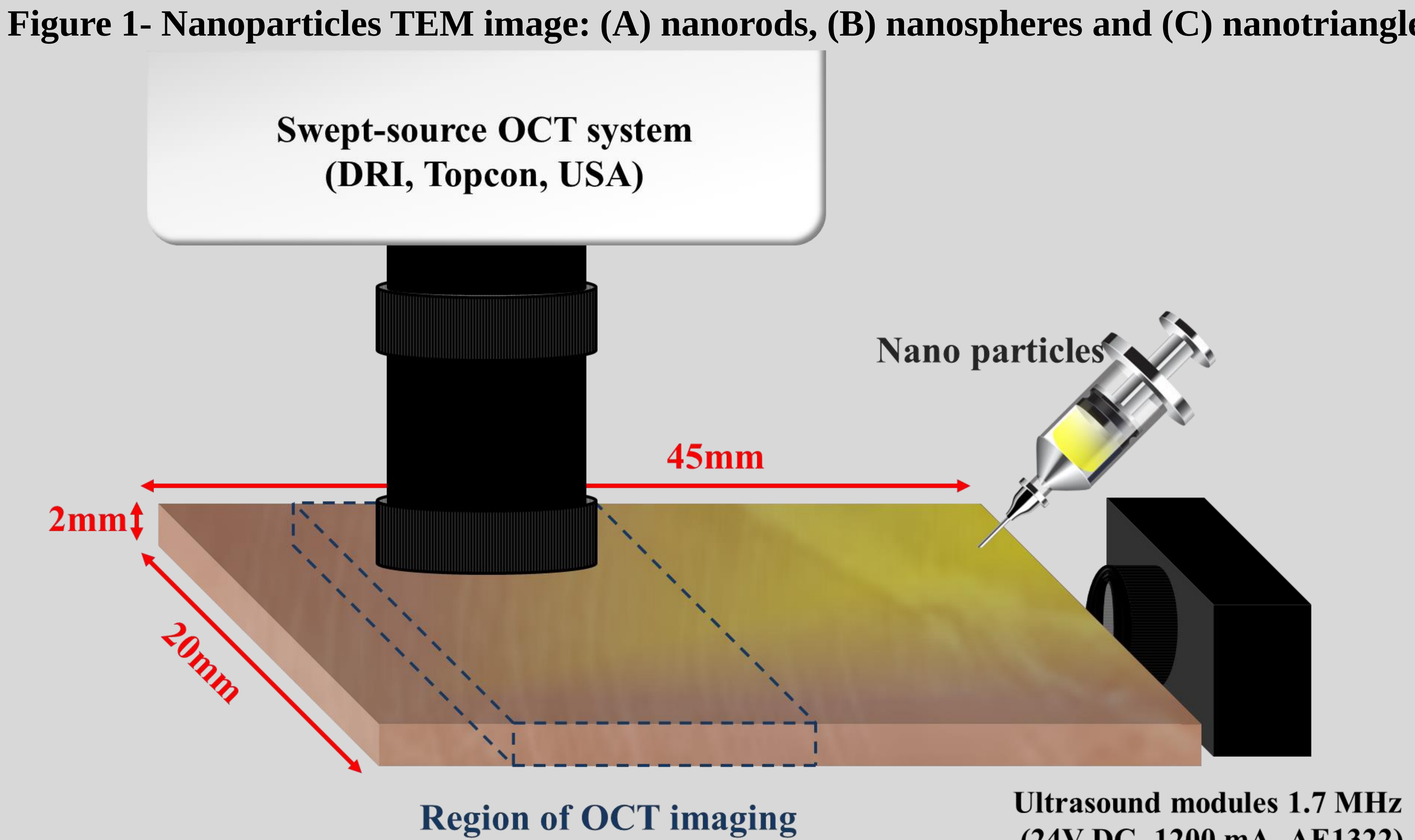

Figure 2- schematics of experimental setup.

Results

1- OCT images in each row show before, after 30 and 60 minutes the injection of nanoparticles respectively. The last image of each row is the signal of ROI (Figure 3)
2- The images show that after 30 minutes, the nanoparticles are not completely distributed in the imaging area. While after 60 minutes, this distribution is more complete. The most CNR is related to the nanotriangle. After nanotriangle, nanorod produces better CNR than nanosphere. This issue is related to the anisotropy that nanoparticles create in the tissue. (Figure 3).
3- Using an ultrasonic module reduces the time of nanoparticle distribution by approximately 55 minutes (Figure 4). After 5 minutes of use, the nanoparticles reach a proper distribution in the imaging area, and the CNR of the images has reached close to the CNR of the image after 60 minutes. This is a very important achievement.

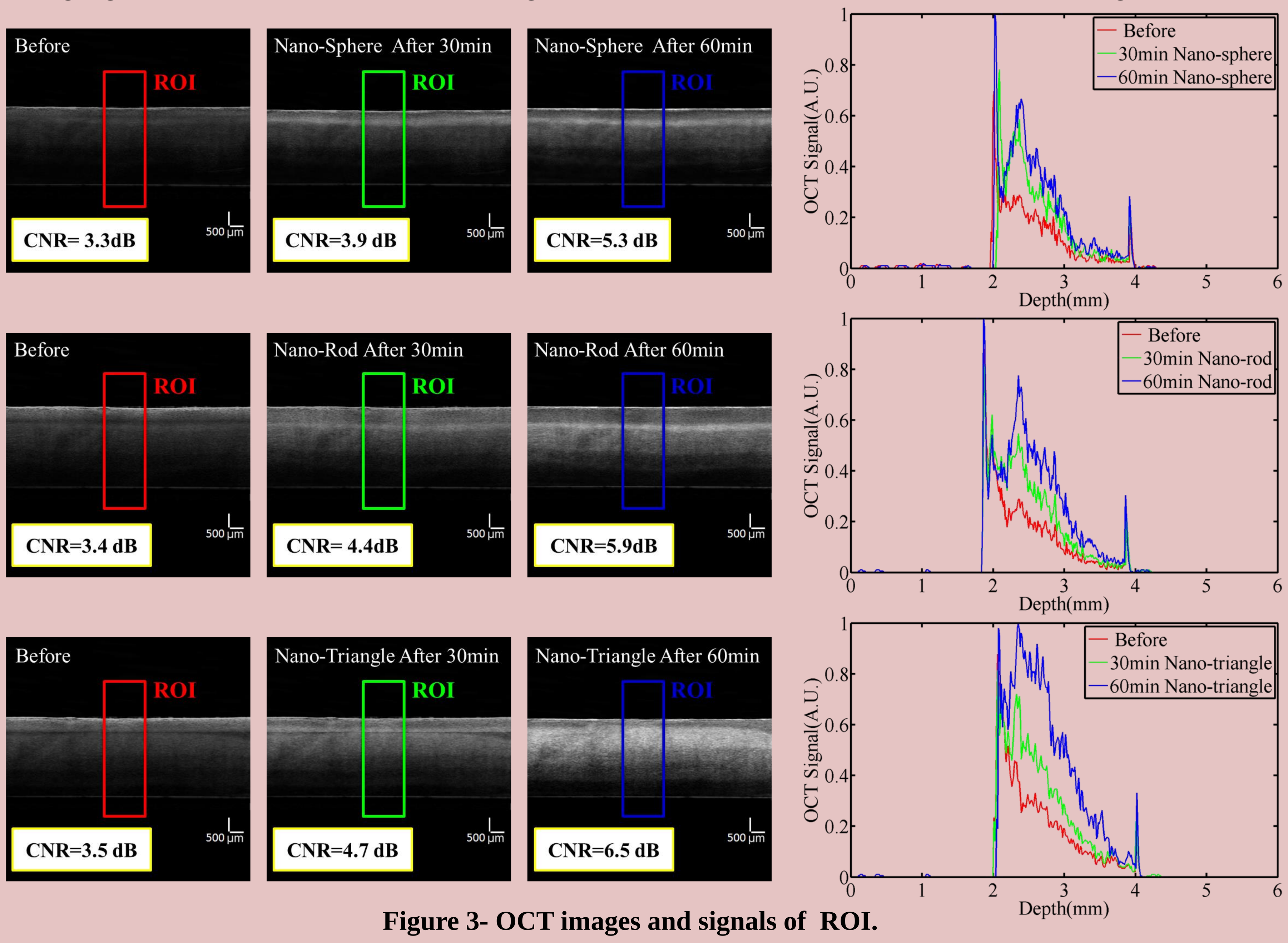

Figure 3- OCT images and signals of ROI.

Figure 4- OCT images in presence of ultrasonic module.

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