Bovine serum albumin (BSA) stabilized radioenhancing nanoparticle (NPs): a comparative study

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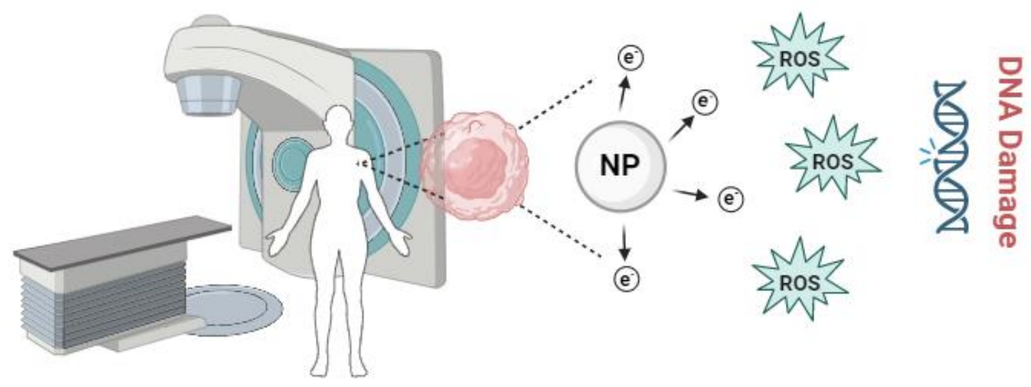
• Introduction

In 2022, there were an estimated 20 million new cancer cases and approximately 9.7 million cancer-related deaths worldwide (IARC, 2024).

Radiotherapy is a fundamental modality in cancer treatment, employing high-energy radiation to destroy cancer cells. Radiation therapy can inadvertently affect nearby healthy tissues or organs, particularly when they are located in close proximity to the tumor. Recently, nanotechnology has demonstrated significant potential in cancer radiotherapy by expanding the therapeutic window[1]. The lack of understanding of nanoparticle (NP)-based radioenhancement hampers strategic material design and limits the effective use of the available material design space[2].

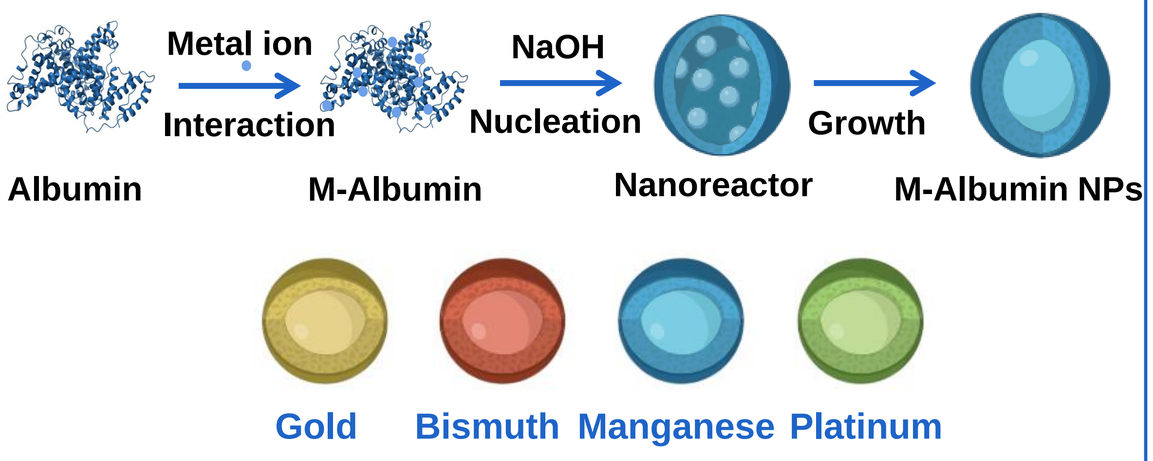
Comparative studies of different materials are essential to better understand the radioenhancing properties of nanomaterials, ultimately enabling the design of optimized radioenhancers for improved therapy outcomes.

Comparing the radioenhancing efficacy of different nanoparticle (NP) systems is challenging due to variations in experimental parameters such as radiation setup, NP properties, cell lines, treatment protocols, and the frequent lack of quantified data. These inconsistencies hinder meaningful cross-study comparisons. Notably, comparative studies indicate that differences in dose enhancement are often attributable to variations in NP size. Therefore, to enable a reliable, head-to-head evaluation of NP composition, it is essential to control for size. The aim of this project is to systematically compare the radioenhancing effects of various nanoparticles of identical size under clinically relevant conditions.



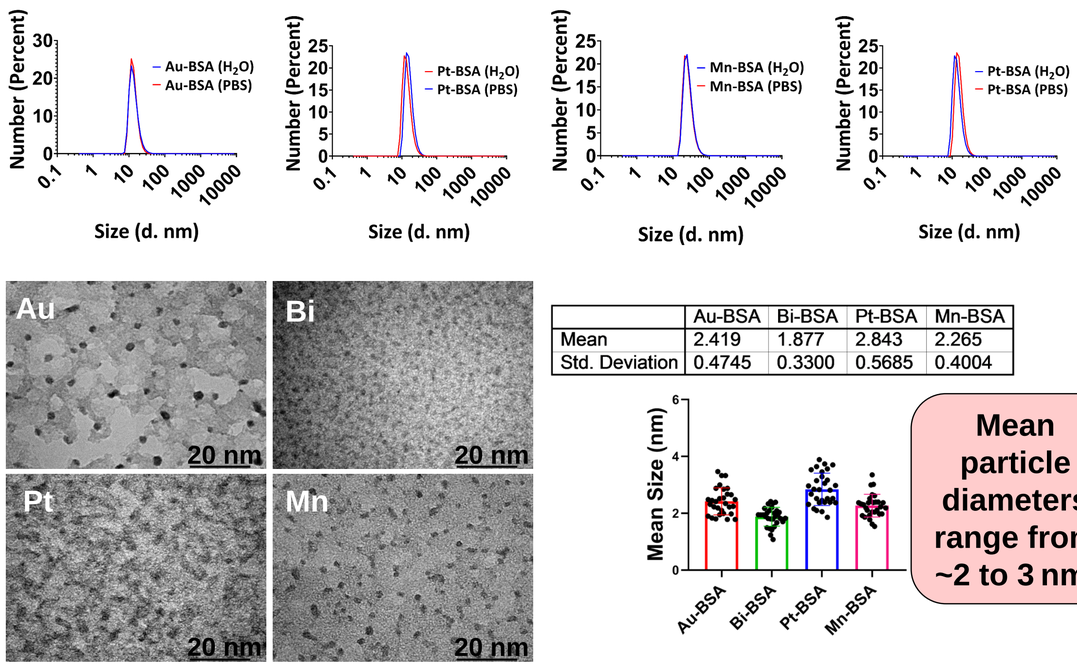
• Synthesis

➢ Biomineralization



Scheme 1. Synthesis route and preparation mechanism of the NPs.

• Characterization



	Au-BSA	Bi-BSA	Pt-BSA	Mn-BSA
Mean	2.419	1.877	2.843	2.265
Std. Deviation	0.4745	0.3300	0.5685	0.4004

Mean particle diameters range from ~2 to 3 nm.

Fig. 1. Size characterization of NPs. Hydrodynamic size distribution measured by dynamic light scattering (DLS), transmission electron microscopy (TEM) images, and the corresponding average particle size of the NPs.

❑ To obtain target NPs with the same size, the effects of factors such as pH, temperature, and reaction time were investigated (data not shown).

• Cytotoxicity

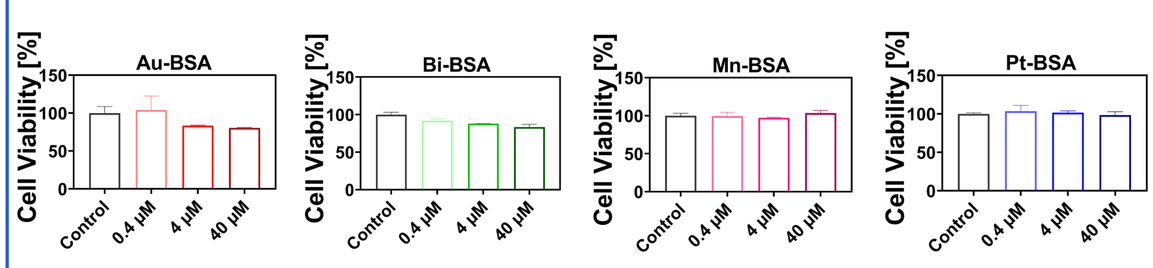


Fig. 2. Biocompatibility study. Effect of NPs treatment on the viability of MCF10a cells.

❑ Cell viability exceeded 80% for all NP formulations.
❑ Mn-BSA and Pt-BSA NPs demonstrated higher biocompatibility with cells compared to Au-BSA and Bi-BSA NPs.

• Dose enhancement

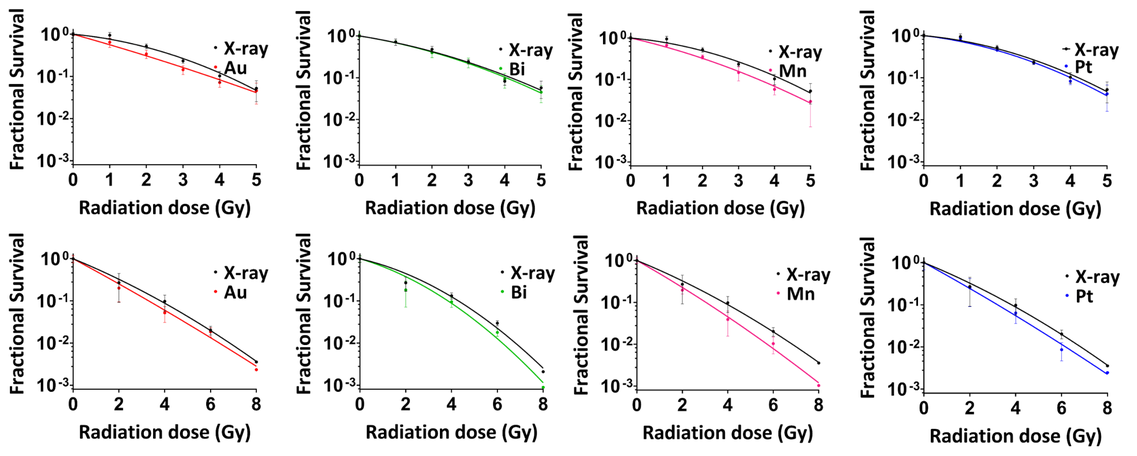


Fig. 3. Clonogenic survival of MCF-7 cancer cells. Surviving fractions of cells irradiated with 250 kV (top row) and 6 MV (bottom row) X-ray beams after 24 h incubation with the respective nanoparticles.

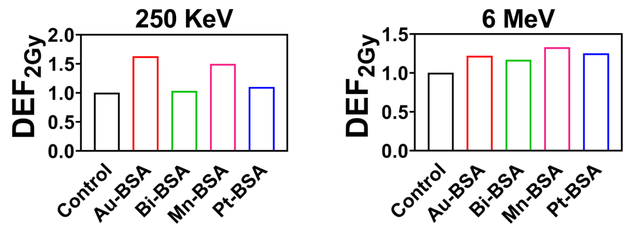


Fig. 4. Dose enhancement factor (DEF) at 2Gy under 250 kVp and 6 MV X-ray energies.

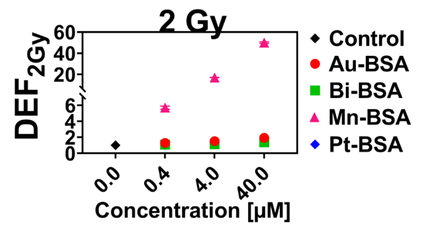


Fig. 5: ROS generation in NP suspensions.

Compared to irradiation alone, all tested nanoparticles (NPs) exhibited an increased DEF, with Mn-BSA NPs showing the greatest enhancement.

• Conclusions

- ➢ Albumin-based biomineralization offers several benefits, including an eco-friendly synthesis process, a simple and reproducible method, high biocompatibility, and excellent stability.
- ➢ The NPs exhibit high stability, even in phosphate-buffered saline (PBS).
- ➢ All NPs were generally well tolerated human mammary epithelial cells (MCF10a).
- ➢ ROS generation by Mn-BSA NPs was superior to that of the other NPs, likely due to their catalytic surface properties.
- ➢ Mn-BSA NPs demonstrated the most pronounced dose-enhancement effect under clinically relevant irradiation conditions.

• Acknowledgements

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• References

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