Novel zinc(II) phthalocyanine nanoparticles as diagnosis-treatment nanoprobe for photoacoustic imaging-guided synergistic photothermal/photodynamic-enhanced cancer therapy

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Calculation of the photothermal conversion efficiency (PCE)

To investigate the intrinsic photothermal property of ZnPcNPs at various concentrations (5, 10, 15, and 20 μmol/L) were treated with 660 nm laser irradiation (0.75 W/cm^2, 5 min). The temperature changes were recorded through the Optris PI infrared camera. Subsequently, the photothermal stability of ZnPcNP at 20.0 μmol/L was evaluated by five consecutive heating and cooling cycles, with laser irradiation on for 5 min and then off for 5 min cooling period during one complete cycle. The temperature during cooling process was measured every 20 s with the IR thermal imaging camera. Phosphate buffered saline (PBS) solution was chosen to be the control group.

The PCE (η) of the aqueous ZnPcNP (20 μmol/L) was calculated according to a previous study.[1] Detailed calculation of η was provided as below:

$$\eta = \frac{hs(T_{Max} - T_{Surr}) - Q_{dis}}{I(1 - 10^{-A_{660}})} \quad \text{……..(2)}$$

where h indicates the heat transfer coefficient, s is the surface area of the sample container, the maximum steady temperature (T_{Max}) of the ZnPcNP solution at 20.0 μmol/L was 57.2°C and environmental temperature (T_{Surr}) was 21.0°C. Thus, the temperature change ($T_{Max} - T_{Surr}$) of the aqueous ZnPcNP was 36.2°C. The power density of laser irradiation at 660 nm (I) was 1 W/cm^2. The absorbance of the ZnPcNP at 660 nm (A_{660}) was 0.55. Next, the value of hs can be calculated through equation (3):

$$hs = \frac{m_D \times c_D}{\tau} \quad \text{……..(3)}$$

where m_D is the mass of sample solution (0.3 g), c_D represents the specific heat capacity of water (c_D = 4.2 J/(g·°C)). The associated time constant during cooling process (τ) was obtained through equation (4):

$$\tau = -\frac{t}{ln(\theta)} \quad \text{……..(4)}$$

where t indicates the time, θ is a dimensionless parameter during cooling process. Next, θ value is introduced as follows:

$$\theta = \frac{T - T_{Surr}}{T_{Max} - T_{Surr}} \quad \text{..... (5)}$$

The Q_{dis} indicates the heat dissipated from the laser absorbed by the PBS solution and plastic tube container, Q_{dis} approximately equals to 0:

Through linear fit analysis (Figure 4e), τ of ZnPcNP solution at (20 μmol/L) was calculated to be 282.1864 s. Therefore, the 660-nm PCE (η) of the ZnPcNP was determined and calculated to be 30.01%.

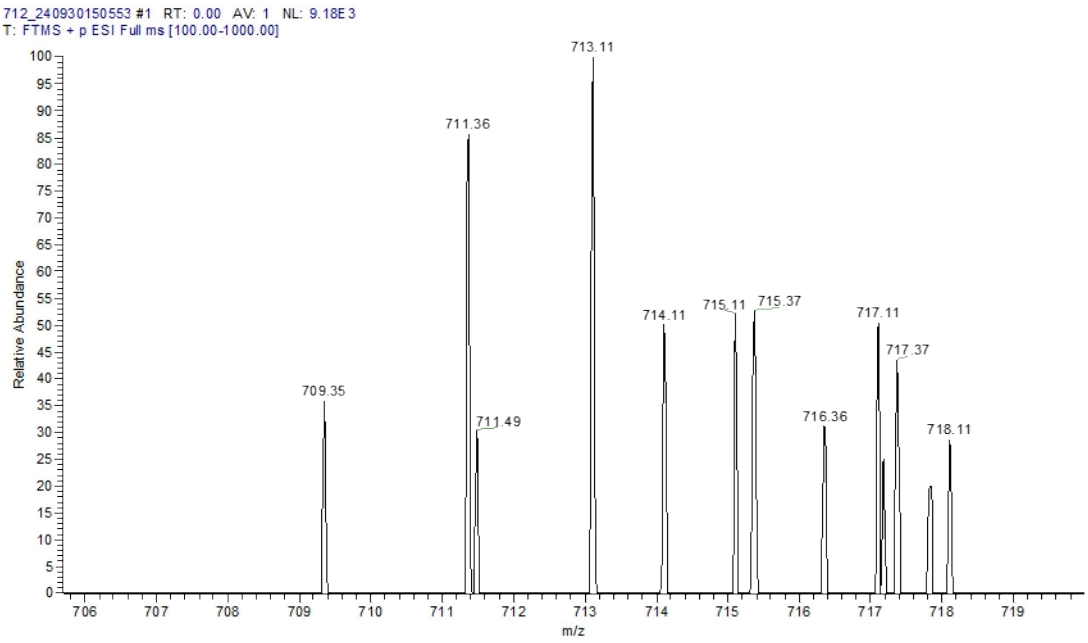

Fig. S1. High-resolution mass spectroscopy (HRMS) spectrum of carboxy-ZnPc **3**.

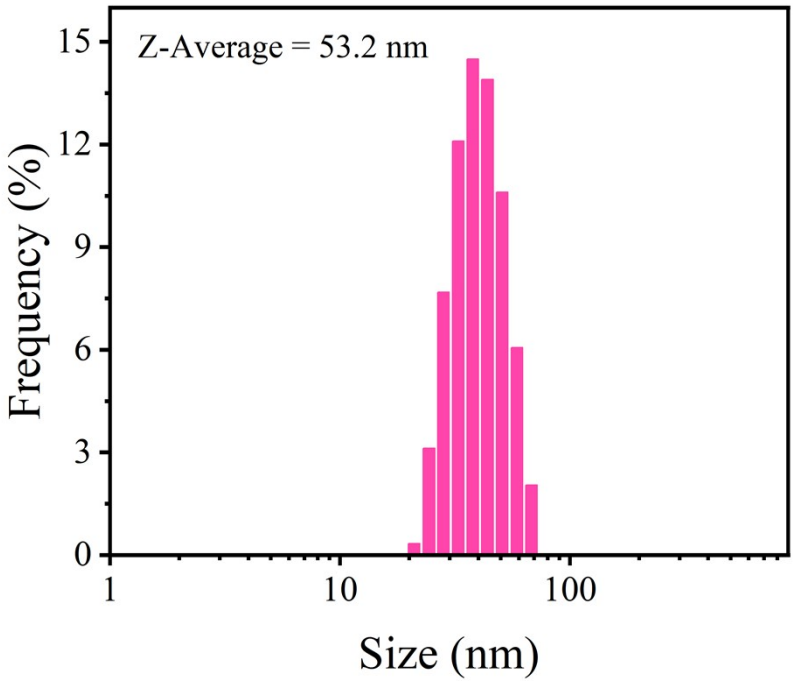

Fig. S2. Dynamic light scattering (DLS) histogram of ZnPcNPs with the Z-average = 53.2 nm and PDI = 0.23.

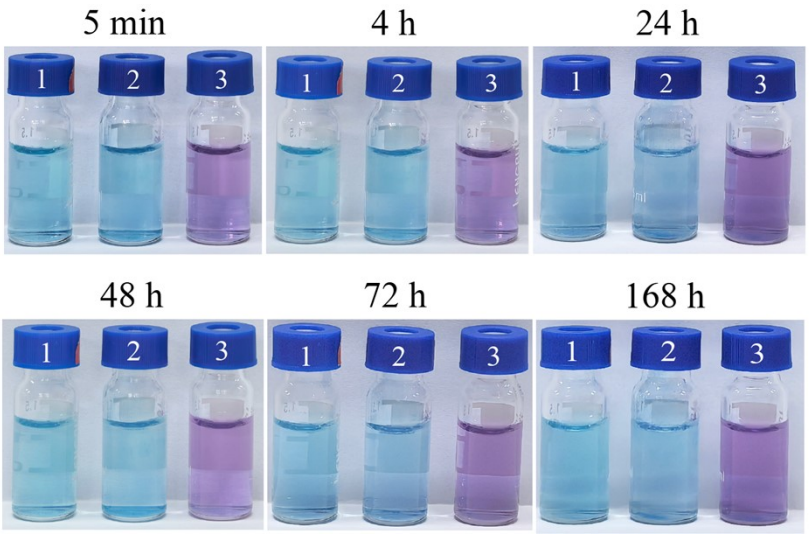

Fig. S3. Photos of ZnPcNPs dispersed in different physiological media, 1: water; 2: PBS solution; 3: RPMI-1640 medium plus 10% fetal bovine serum (FBS), at different time points (5 min, 4 h, 24 h, 48 h, 72 h, and 168 h).

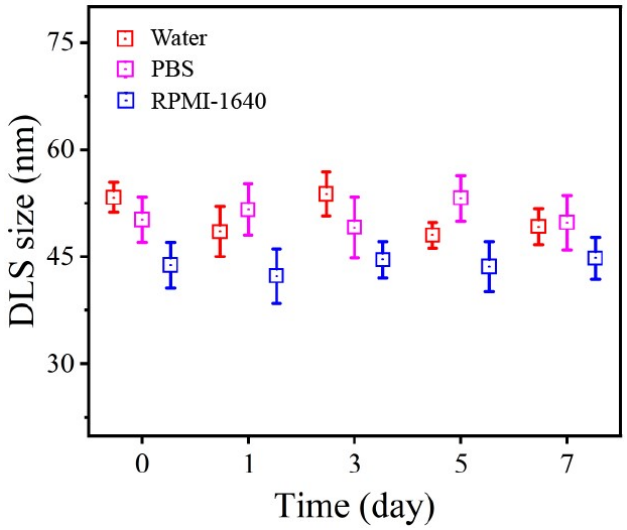

Fig. S4. Dynamic light scattering (DLS) sizes of ZnPcNPs in water, PBS, and RPMI-1640 + 10% FBS at 0, 1, 3, 5, and 7 days.

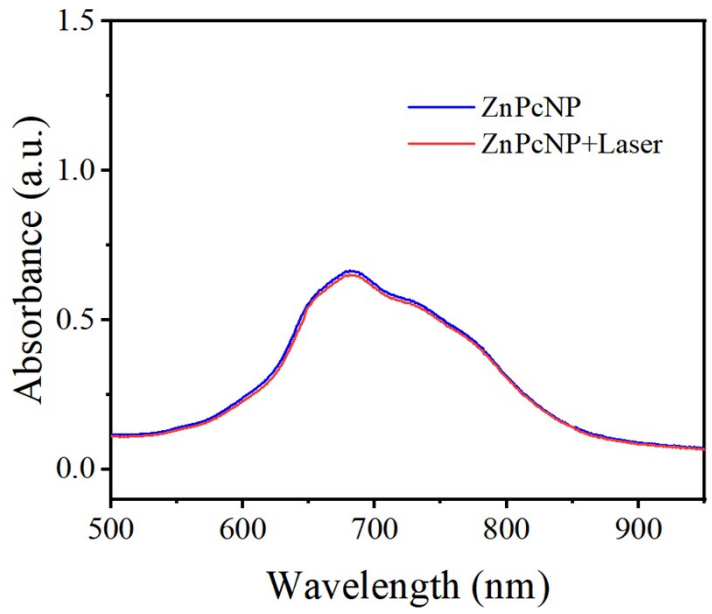

Fig. S5. Ultraviolet-visible (UV-Vis) spectra of aqueous ZnPcNPs before and after NIR-I laser irradiation (660 nm, 0.75 W/cm^2, 5 min).

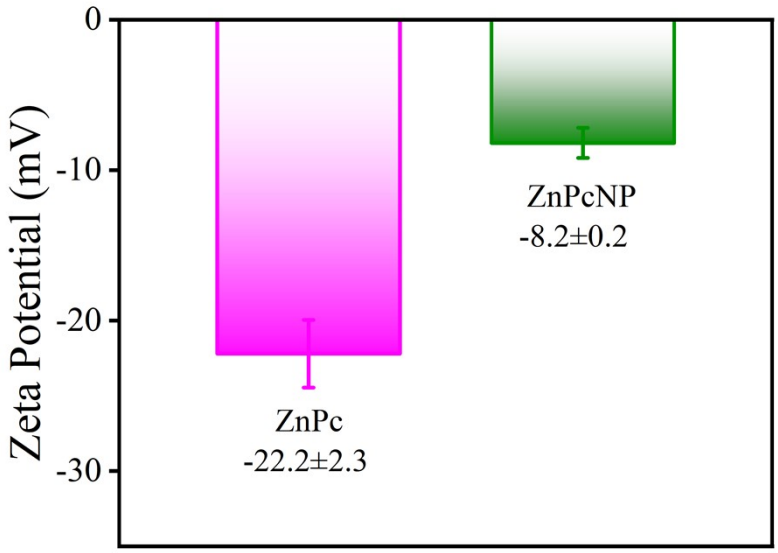

Fig. S6. Zeta potential of ZnPc and ZnPcNP.

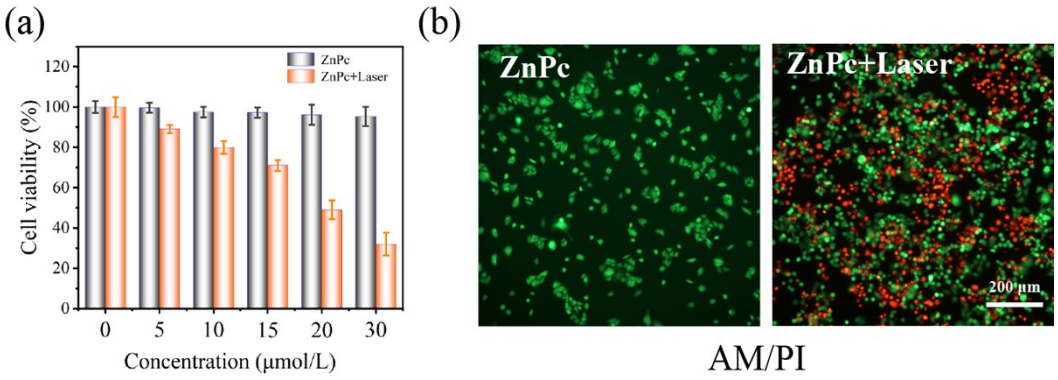

Fig. S7. (a) Cell viability of ZnPc before and after NIR-I laser treatment (660 nm, 0.75 W/cm^2, 5 min). (b) Fluorescence images of 4T1 cancer cells co-stained by Calcein-AM/PI dyes under ZnPc and 'ZnPc + Laser' treatments.

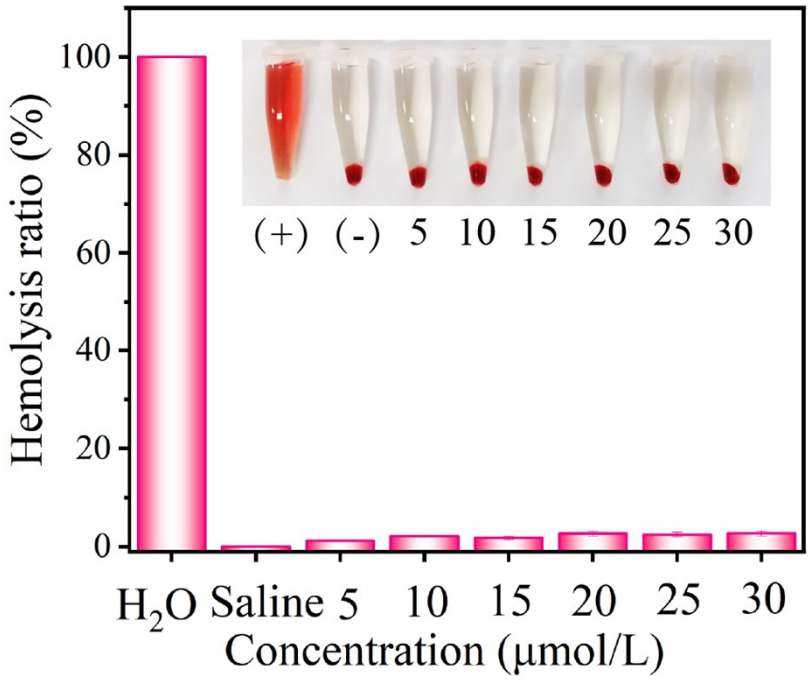

Fig. S8. Hemolysis assay with different concentrations of aqueous ZnPcNPs (5, 10, 15, 20, 25, and 30 μmol/L), saline (-), and deionized water (+).

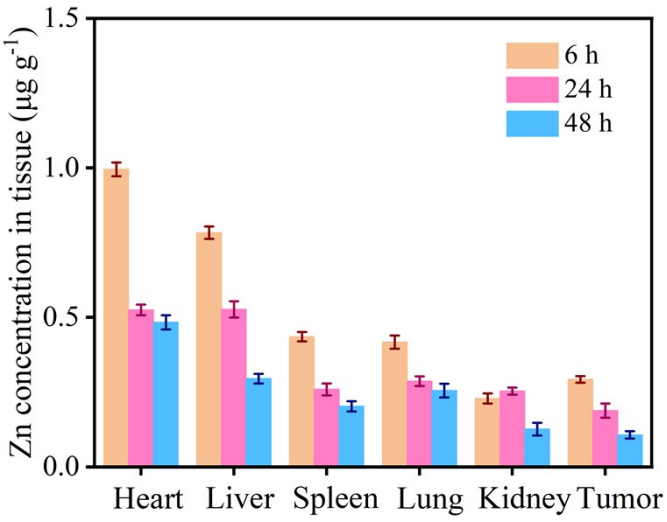

Fig. S9. Biodistribution after intravenous injection of aqueous ZnPcNPs for various time intervals (6, 24, and 48 h).

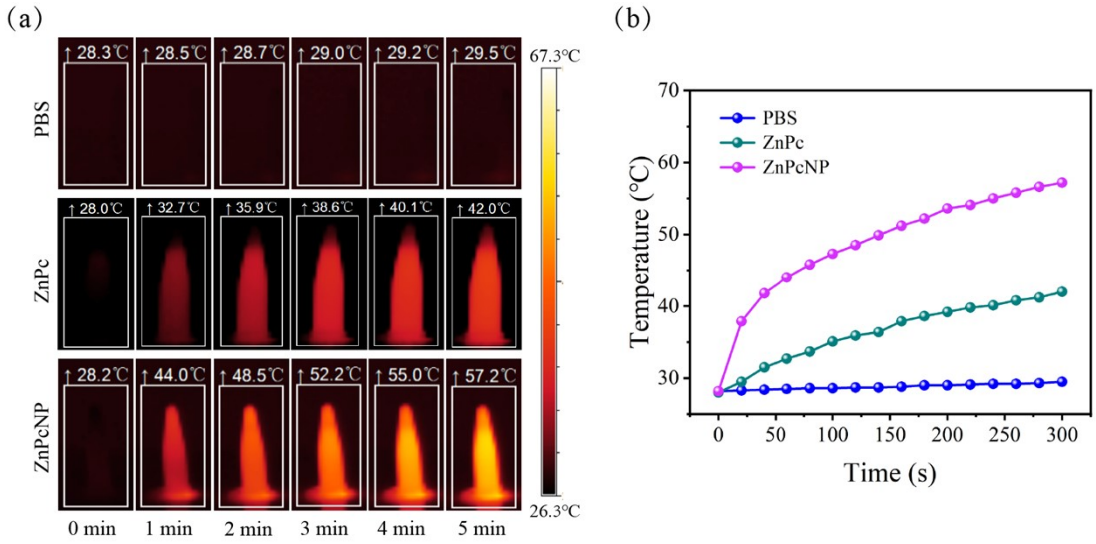

Fig. S10. (a) Infrared thermal pictures of PBS, ZnPc (20 μmol/L) and ZnPcNP (20 μmol/L). (b) The photothermal response curves correlated with Fig. S10a.

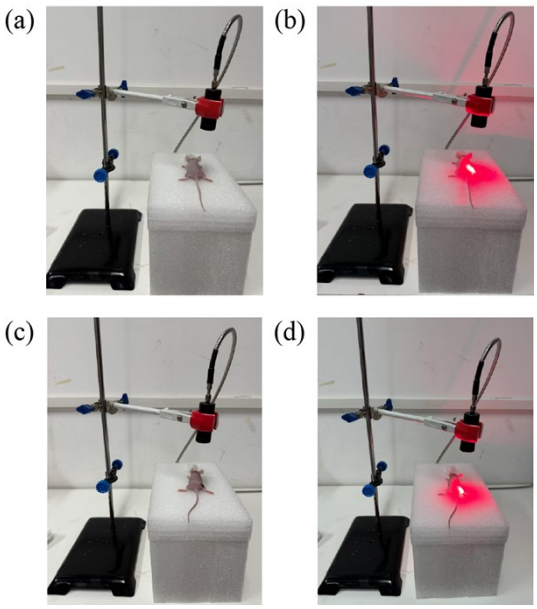

Fig. S11. (a, c) Intravenous administration of (a) solely PBS or (c) aqueous ZnPcNPs before NIR-I laser treatment. (b, d) NIR-I laser treatment (660 nm, 0.75 W/cm^2, 5 min) for (b) 'PBS + Laser' or (d) 'ZnPcNP + Laser' groups, respectively.

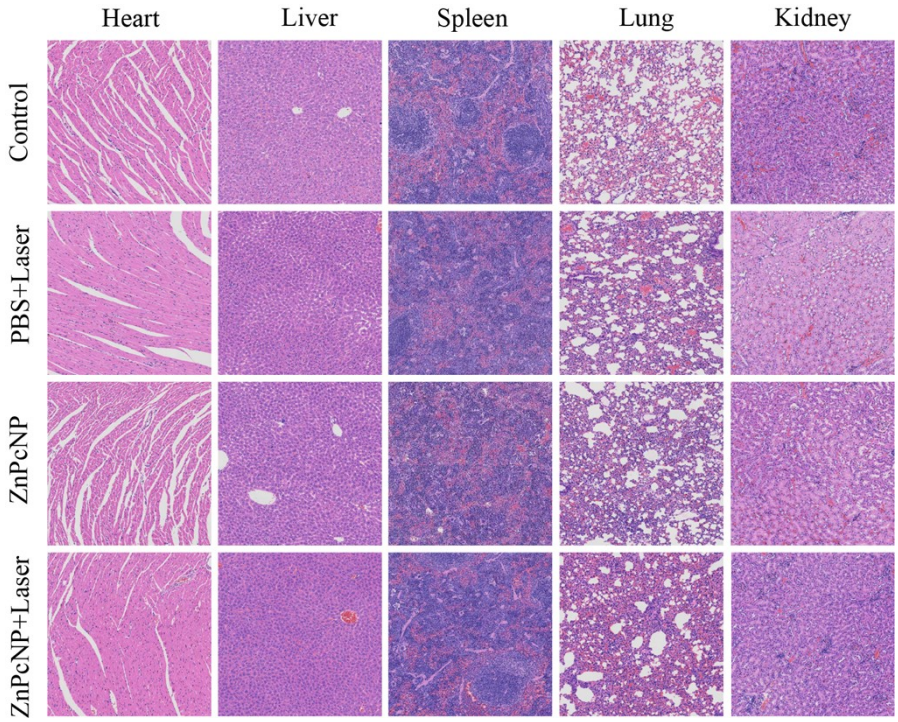

Fig. S12. H&E images of major organs (heart, liver, spleen, lung, and kidney) after different treatments.

September 18th, 2024

Animal Care and Ethical Examination Certificate

(No.202409-002)

Protocol Title: Novel Zinc(II) Phthalocyanine Nanoparticles for Photoacoustic Imaging-Guided Synergistic Photothermal/Photodynamic Therapy

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All animal procedures in the manuscript entitled "Novel Zinc(II) Phthalocyanine Nanoparticles for Photoacoustic Imaging Guided Synergistic Photothermal/Photodynamic Therapy" reported by Min He, Yidong Bin, Lixian Huang, Caiying Li, Yuzhen Ma, Yanni Luo, Shulin Zhao, and Jinzhe Liang were performed in accordance with the guidelines of Institutional Animal Care and Use Committee (IACUC) and were approved by the Laboratory Animal Care and Animal Ethics Committee of Guangxi Normal University.

Laboratory Animal Care and Animal Ethics Committee

of Guangxi Normal University

Fig. S13. The Animal Care and Ethical Examination Certificate (Approval No.: GXNU-No.202409-002).

Reference

1. J. Li, J. Wang, J. Zhang, T. Han, X. Hu, M. M. S. Lee, D. Wang and B. Z. Tang, A Facile Strategy of Boosting Photothermal Conversion Efficiency through State Transformation for Cancer Therapy, Adv. Mater., 2021, 33, 2105999.