Curcumin-gold nanoshell mediated near-infrared irradiation on human ovarian cancer cell: in vitro study

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Aims and scope

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Abstract

Ovarian cancer is considered a predominant female reproductive malignancy and poses a significant threat due to its 80–90% fatality rate.

The typical approach involves surgery and chemotherapy, which due to problems such as drug resistance, encourage researchers to use new methods such as nanotechnology. The current study introduces a novel strategy: leveraging Curcumin-Gold Nanoshells (Cur-AuNShs) to combat chemotherapy's adverse effects and overcome drug resistance through hyperthermia mediation. Gold-based nanoparticles that absorb laser have shown the potential to target and treat cancer selectively through highly efficient light-to-heat conversion. This experimental study focused on the synthesis of AuNShs and their subsequent conjugation with Cur. The gold shell coverage on the surfaces of silica nanoparticles was examined using UV–VIS spectroscopy and transmission electron microscopy (TEM). Dynamic light scattering (DLS) and Zeta potential analysis were employed to evaluate the stability of particle size and surface charge. Human ovarian carcinoma cell lines (SKOV-3) were treated with a combination of Cur (15 μM) and AuNShs (75 μM), under the activation of near-infrared (NIR) laser irradiation at a power of 2.5 W/cm^3 for 5 or 10 min. Cell viability was then assessed using the MTT assay. Lastly, the expression levels of Bax, Bcl2, and HSPB1 genes were analyzed using the real-time polymerase chain reaction (real-time PCR) technique. The average diameter of the AuNShs was measured at 70 ± 7.1 nm. Findings revealed that after a 48 h incubation with Cur-AuNShs followed by 10 min of laser irradiation, cell viability decreased significantly from 44.3 ± 1.7 to 14.4 ± 1. Analysis using real-time PCR showed an increase in Bax expression alongside a decrease in Bcl2 expression. Additionally, the expression of the HSPB1 gene was reduced from 1.35 ± 1 to 0.9 ± 0.65 in the laser-treated Cur-AuNShs-NIR group. The AuNShs, when combined with hyperthermia at 43 °C, demonstrated potential as an effective carrier for Cur

administration. This combination was associated with a greater activation of apoptosis compared to the free drug.

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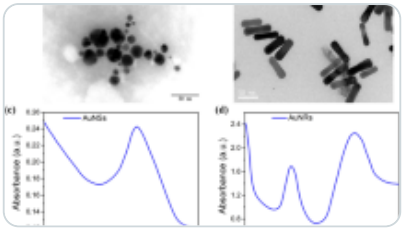

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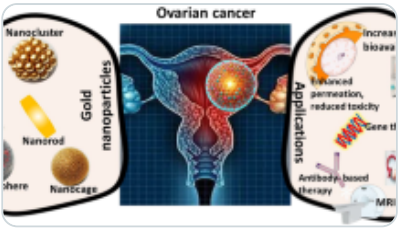

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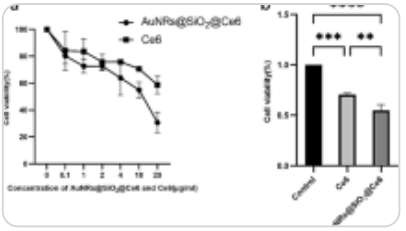

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Data availability

No datasets were generated or analyzed during the current study.

References

1. Ames B, Gold L, editors. Natural chemicals, synthetic chemicals, risk assessment, and cancer. Princess Takamatsu symposia; 1990.

2. Khan S. Potential role of *Escherichia coli* DNA mismatch repair proteins in colon cancer. Crit Rev Oncol Hematol. 2015;96(3):475–82.

Article PubMed Google Scholar

3. Khan S, Mosvi SN, Vohra S, Poddar NK. Implication of calcium supplementations in health and diseases with special focus on colorectal cancer. Crit Rev Clin Lab Sci. 2024;61(6):496–509.

Article CAS PubMed Google Scholar

4. Khan S, Zakariah M, Rolfo C, Robrecht L, Palaniappan S. Prediction of mycoplasma hominis proteins targeting in mitochondria and cytoplasm of host cells and their implication in prostate cancer etiology. Oncotarget. 2016;8(19):30830.

Article PubMed Central Google Scholar

5. Khan S, Zakariah M, Palaniappan S. Computational prediction of Mycoplasma hominis proteins targeting in nucleus of host cell and their implication in prostate cancer etiology. Tumor Biol. 2016;37:10805–13.

Article Google Scholar

6. Khan S, Imran A, Khan AA, Abul Kalam M, Alshamsan A. Systems biology approaches for the prediction of possible role of *Chlamydia*

pneumoniae proteins in the etiology of lung cancer. PLoS ONE. 2016;11(2): e0148530.

Article PubMed PubMed Central Google Scholar

7. Wang Y, Imran A, Shami A, Chaudhary AA, Khan S. Decipher the *Helicobacter pylori* protein targeting in the nucleus of host cell and their implications in gallbladder cancer: an insilico approach. J Cancer. 2021;12(23):7214.

Article CAS PubMed PubMed Central Google Scholar

8. Khan S, Zaidi S, Alouffi AS, Hassan I, Imran A, Khan RA. Computational proteome-wide study for the prediction of *Escherichia coli* protein targeting in host cell organelles and their implication in development of colon cancer. ACS Omega. 2020;5(13):7254–61.

Article CAS PubMed PubMed Central Google Scholar

9. Reid BM, Permuth JB, Sellers TAJCb. Epidemiology of ovarian cancer: a review. Cancer Biol Med. 2017;14(1):9.

Article CAS PubMed PubMed Central Google Scholar

10. Vallius T, Hynninen J, Kemppainen J, Alves V, Auranen K, Matomäki J, et al. 18 F-FDG-PET/CT based total metabolic tumor volume change during neoadjuvant chemotherapy predicts outcome in

advanced epithelial ovarian cancer. Eur J Nucl Med Mol Imaging. 2018;45:1224–32.

Article CAS PubMed Google Scholar

11. Zielińska A, Alves H, Marques V, Durazzo A, Lucarini M, Alves TF, et al. Properties, extraction methods, and delivery systems for curcumin as a natural source of beneficial health effects. Medicina. 2020;56(7):336.

Article PubMed PubMed Central Google Scholar

12. Weir NM, Selvendiran K, Kutala VK, Tong L, Vishwanath S, Rajaram M, et al. Curcumin induces G2/M arrest and apoptosis in cisplatin-resistant human ovarian cancer cells by modulating akt and p38 mAPK. Cancer Biol Ther. 2007;6(2):178–84.

Article CAS PubMed Google Scholar

13. Lu H-F, Lai K-C, Hsu S-C, Lin H-J, Yang M-D, Chen Y-L, et al. Curcumin induces apoptosis through FAS and FADD, in caspase-3-dependent and-independent pathways in the N18 mouse-rat hybrid retina ganglion cells. Oncol Rep. 2009;22(1):97–104.

CAS PubMed Google Scholar

14. Chen X-P, Li Y, Zhang Y, Li G. Formulation, characterization and evaluation of curcumin-loaded PLGA-TPGS nanoparticles for liver

cancer treatment. Drug Design Dev Ther. 2019;13:3569–78.

Article CAS Google Scholar

15. Hak A, Shinde VR, Rengan AKJP, Therapy P. A review of advanced nanoformulations in phototherapy for cancer therapeutics. Photodiagn Photodyn Ther. 2021;33: 102205.

Article CAS Google Scholar

16. Malviya N, Malviya S, Saxena R, Chauhan V, Dhere M. Smart biodegradable polymeric nanoparticles: synthesis, characterization, and applications. In: Advancements in controlled drug delivery systems. New York: IGI Global; 2022. p. 257–80.

Chapter Google Scholar

17. Ombredane AS, Silva VR, Andrade LR, Pinheiro WO, Simonelly M, Oliveira JV, et al. In vivo efficacy and toxicity of curcumin nanoparticles in breast cancer treatment: a systematic review. Front Oncol. 2021;11: 612903.

Article CAS PubMed PubMed Central Google Scholar

18. Sun L, Xu H,Xu J-h, Wang S-N, Wang J-W, Zhang H-F, et al. Enhanced antitumor efficacy of curcumin-loaded PLGA nanoparticles coated with unique fungal hydrophobin. AAPS PharmSciTech. 2020;21:1–10.

Article Google Scholar

19. Ipar VS, Dsouza A, Devarajan PVJE. Enhancing curcumin oral bioavailability through nanoformulations. Eur J Drug Metab Pharmacokinet. 2019;44:459–80.

Article CAS PubMed Google Scholar

20. Elahi N, Kamali M, Baghersad MHJT. Recent biomedical applications of gold nanoparticles: a review. Talanta. 2018;184:537–56.

Article CAS PubMed Google Scholar

21. Nambiar S, Osei E, Fleck A, Darko J, Mutsaers AJ, Wettig SJAN. Synthesis of curcumin-functionalized gold nanoparticles and cytotoxicity studies in human prostate cancer cell line. Appl Nanosci. 2018;8:347–57.

Article CAS Google Scholar

22. Mahmoudi A, Kesharwani P, Majeed M, Teng Y, Sahebkar AJC, Biointerfaces SB. Recent advances in nanogold as a promising nanocarrier for curcumin delivery. Colloids Surf B. 2022;215: 112481.

Article CAS Google Scholar

23. Yan T, Su M, Wang Z, Zhang JJS. Second near-infrared plasmonic nanomaterials for photoacoustic imaging and photothermal therapy. Small. 2023;19(30):2300539.

Article CAS Google Scholar

24. Phuong PTM, Jhon H, In I. Photothermal-modulated reversible volume transition of wireless hydrogels embedded with redox-responsive carbon dots. Biomater Sci. 2019;7(11):4800–12.

Article CAS PubMed Google Scholar

25. Riley RS, Day ESJ. Gold nanoparticle-mediated photothermal therapy: applications and opportunities for multimodal cancer treatment. Wiley Interdisc Rev. 2017;9(4): e1449.

Google Scholar

26. Ghobashy MM, Alkhursani SA, Alqahtani HA, El-damhougy TK, Madani MJMS. Gold nanoparticles in microelectronics advancements and biomedical applications. Mater Sci Eng. 2024;301:117191.

Article CAS Google Scholar

27. De Matteis V, Cascione M, Toma CC, Rinaldi RJC. Engineered gold nanoshells killing tumor cells: new perspectives. Curr Pharm Design. 2019;25(13):1477–89.

Article Google Scholar

28. Nouri S, Mohammadi E, Mehravi B, Majidi F, Ashtari K, Neshasteh-Riz A, et al. NIR triggered glycosylated gold nanoshell as a photothermal agent on melanoma cancer cells. Artif Cells Nanomed Biotechnol. 2019;47(1):2316–24.

Article CAS PubMed Google Scholar

29. Martin RC, Locatelli E, Li Y, Zhang W, Li S, Monaco I, et al. Gold nanorods and curcumin-loaded nanomicelles for efficient in vivo photothermal therapy of Barrett's esophagus. Nanomedicine. 2015;10(11):1723–33.

Article CAS PubMed Google Scholar

30. Kayani Z, Vais RD, Soratijahromi E, Mohammadi S, Sattarahmady NJP, Therapy P. Curcumin-gold-polyethylene glycol nanoparticles as a nanosensitizer for photothermal and sonodynamic therapies: in vitro and animal model studies. Photodiagn Photodyn Ther. 2021;33:102139.

Article CAS Google Scholar

31. Singh SP, Alvi SB, Pemmaraju DB, Singh AD, Manda SV, Srivastava R, et al. NIR triggered liposome gold nanoparticles entrapping

curcumin as in situ adjuvant for photothermal treatment of skin cancer. Int J Biol Microbiol. 2018;110:375–82.

Article CAS Google Scholar

32. Heiserman JP, Nallanthighal S, Gifford CC, Graham K, Samarakoon R, Gao C, et al. Heat shock protein 27, a novel downstream target of collagen type XI alpha 1, synergizes with fatty acid oxidation to confer cisplatin resistance in ovarian cancer cells. Cancers. 2021;13(19):4855.

Article CAS PubMed PubMed Central Google Scholar

33. Bilous I, Pavlovych L, Krynytska I, Marushchak M, Kamyshnyi A. Apoptosis and cell cycle pathway-focused genes expression analysis in patients with different forms of thyroid pathology. 2020.

34. Ren G, Su H, Wang SJJ. The combined method to synthesis silica nanoparticle by Stöber process. J Sol-Gel Sci Technol. 2020;96:108–20.

Article CAS Google Scholar

35. García-Soto MJ, González-Ortega OJGB. Synthesis of silica-core gold nanoshells and some modifications/variations. Gold Bull. 2016;49:111–31.

Article Google Scholar

36. Gao Y, Torrente-Murciano LJN. Mechanistic insights of the reduction of gold salts in the Turkevich protocol. Nanoscale. 2020;12(4):2740–51.

Article CAS PubMed Google Scholar

37. Oćwieja M, Maciejewska-Prończuk J, Adamczyk Z, Roman MJ. Formation of positively charged gold nanoparticle monolayers on silica sensors. J Colloid Interface Sci. 2017;501:192–201.

Article PubMed Google Scholar

38. dos Santos CD, Teixeira BH, Pereira CBP, Franzolin MR. Pegylated curcumin with gold nanoparticles: antimicrobial agent evaluation. J Biomed Eng Biosci. 2016;3(1):43–7.

Google Scholar

39. Sharma K, Agrawal S, Gupta MJIJDDR. Development and validation of UV spectrophotometric method for the estimation of curcumin in bulk drug and pharmaceutical dosage forms. Int J Drug Dev Res. 2012;4(2):375–80.

CAS Google Scholar

40. Alwattar JK, Mneimneh AT, Abla KK, Mehanna MM, Allam ANJP. Smart stimuli-responsive liposomal nanohybrid systems: a critical review of theranostic behavior in cancer. Pharmaceutics. 2021;13(3):355.

Article CAS PubMed PubMed Central Google Scholar

41. Chaichian S, Kashi AM, Tehermanesh K, Mahabadi VP, Minaeian S, Eslahi NJCJ. Effect of PLGA nanoparticle-mediated delivery of MiRNA 503 on the apoptosis of ovarian endometriosis cells. Cell J. 2022;24(11):697.

PubMed PubMed Central Google Scholar

42. Shanmugam MK, Rane G, Kanchi MM, Arfuso F, Chinnathambi A, Zayed M, et al. The multifaceted role of curcumin in cancer prevention and treatment. Molecules. 2015;20(2):2728–69.

Article PubMed PubMed Central Google Scholar

43. Doello K, Ortiz R, Alvarez PJ, Melguizo C, Cabeza L, Prados JJN, et al. Latest in vitro and in vivo assay, clinical trials and patents in cancer treatment using curcumin: a literature review. Nutr Cancer. 2018;70(4):569–78.

Article CAS PubMed Google Scholar

44. Rastinehad AR, Anastos H, Wajswol E, Winoker JS, Sfakianos JP, Doppalapudi SK, et al. Gold nanoshell-localized photothermal ablation of prostate tumors in a clinical pilot device study. Proc Natl Acad Sci. 2019;116(37):18590–6.

Article CAS PubMed PubMed Central Google Scholar

45. Kong X-X, Jiang S, Liu T, Liu G-F, Dong M. Paclitaxel increases sensitivity of SKOV3 cells to hyperthermia by inhibiting heat shock protein 27. Biomed Pharmacother. 2020;132: 110907.

Article CAS PubMed Google Scholar

46. Yu Z, Wan Y, Liu Y, Yang J, Li L, Zhang W. Curcumin induced apoptosis via PI3K/Akt-signalling pathways in SKOV3 cells. Pharm Biol. 2016;54(10):2026–32.

Article CAS PubMed Google Scholar

47. Woźniak A, Malankowska A, Nowaczyk G, Grześkowiak BF, Tuśnio K, Słomski R, et al. Size and shape-dependent cytotoxicity profile of gold nanoparticles for biomedical applications. J Mater Sci. 2017;28:1–11.

Google Scholar

48. Xia Q, Huang J, Feng Q, Chen X, Liu X, Li X, et al. Size-and cell type-dependent cellular uptake, cytotoxicity and in vivo distribution of

gold nanoparticles. Int J Nanomed. 2019;14:6957–70.

Article CAS Google Scholar

49. Rezakhani L, Fekri K, Rostaminasab G, Rahmati SJMO. Exosomes: special nano-therapeutic carrier for cancers, overview on anticancer drugs. Med Oncol. 2022;40(1):31.

Article PubMed Google Scholar

50. Piktel E, Ościłowska I, Suprewicz Ł, Depciuch J, Marcińczyk N, Chabielska E, et al. ROS-mediated apoptosis and autophagy in ovarian cancer cells treated with peanut-shaped gold nanoparticles. Int J Nanomed. 2021;16:1993.

Article Google Scholar

51. Alipour S, Babaei G, Aziz SG-G, Abolhasani S. Alantolactone and ZnO nanoparticles induce apoptosis activity of cisplatin in an ovarian cancer cell line (SKOV3). Res Pharm Sci. 2022;17(3):294.

Article PubMed PubMed Central Google Scholar

52. Abedi M, Babaei E. Study of the effect of dendrosomal nano-curcumin on expression of apoptotic Bax and Bcl2 genes in cancerous cell line AGS. J Police Med. 2015;3(4):203–10.

Google Scholar

53. Chen C-H, Chan T-M, Wu Y-J, Chen J-J. Application of nanoparticles in urothelial cancer of the urinary bladder. J Med Biol Eng. 2015;35:419–27.

Article CAS PubMed PubMed Central Google Scholar

54. Rau L-R, Huang W-Y, Liaw J-W, Tsai S-W. Photothermal effects of laser-activated surface plasmonic gold nanoparticles on the apoptosis and osteogenesis of osteoblast-like cells. Int J Nanomed. 2016;11:3461.

Article CAS Google Scholar

55. Liang Z, Li X, Xie Y, Liu S. 'Smart'gold nanoshells for combined cancer chemotherapy and hyperthermia. Biomed Mater. 2014;9(2): 025012.

Article CAS PubMed Google Scholar

56. Lee S-Y, Shieh M-J. Platinum (II) drug-loaded gold nanoshells for chemo-photothermal therapy in colorectal cancer. ACS Appl Mater Interfaces. 2020;12(4):4254–64.

Article CAS PubMed Google Scholar

57. Yang S-J, Pai J-A, Shieh M-J, Chen JLY, Chen K-C. Cisplatin-loaded gold nanoshells mediate chemo-photothermal therapy against primary and distal lung cancers growth. Biomed Pharmacother. 2023;158: 114146.

Article CAS PubMed Google Scholar

58. Emamzadeh M, Pasparakis G. Polymer coated gold nanoshells for combinational photochemotherapy of pancreatic cancer with gemcitabine. Sci Rep. 2021;11(1):9404.

Article CAS PubMed PubMed Central Google Scholar

59. Pourgholi A, Dadashpour M, Mousapour A, Amandi AF, Zarghami N. Anticancer potential of silibinin loaded polymeric nanoparticles against breast cancer cells: insight into the apoptotic genes targets. Asian Pac J Cancer Prev. 2021;22(8):2587.

Article CAS PubMed PubMed Central Google Scholar

60. Hassani N, Jafari-Gharabaghlou D, Dadashpour M, Zarghami N. The effect of dual bioactive compounds artemisinin and metformin co-loaded in PLGA-PEG nano-particles on breast cancer cell lines: potential apoptotic and anti-proliferative action. Appl Biochem Biotechnol. 2022;194(10):4930–45.

Article CAS Google Scholar

61. Azar LK, Dadashpour M, Hashemi M, Zarghami N. Design and development of nanostructured co delivery of artemisinin and chrysin for targeting hTERT gene expression in breast cancer cell line: possible clinical application in cancer treatment. Asian Pac J Cancer Prev. 2022;23(3):919.

Article CAS Google Scholar

62. Wang H-X, Yang Y, Guo H, Hou D-D, Zheng S, Hong Y-X, et al. HSPB1 deficiency sensitizes melanoma cells to hyperthermia induced cell death. Oncotarget. 2016;7(41):67449.

Article PubMed PubMed Central Google Scholar

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Contributions

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Ethics declarations

Conflict of interest

The authors declare that there is no conflict of interest in this study.

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