

# Gold Nanoparticles in Nuclear Medicine

Alan Biju

March 19, 2022

## Abstract

Novel optical and physicochemical properties of gold nanoparticles have acquired expanded interest as radiosensitizing, photothermal treatment, and optical imaging specialists to upgrade the viability of malignant growth location and treatment. Besides, their capacity to convey different therapeutically significant radionuclides expands their use to atomic medication SPECT and PET imaging as well as designated radionuclide treatment. In this paper, we talk about the radiolabeling system of gold nanoparticles and their utilization in (multimodal) atomic medication imaging to better comprehend their particular dissemination, take-up, the advantage of nanomaterial in nuclear medicine and maintenance in various in vivo malignant growth models.

## An introduction in nuclear medicine

Nuclear medicine includes the inward organization of radionuclides to analyze, stage, treat, and follow-up of infections, including disease. Radiopharmaceuticals are created by connecting a radionuclide to a transporter particle, which is coordinated against a disease explicit antigen or cycle. The choice of the reasonable radionuclide relies upon its particular discharge and the planned application. In more detail, positron (beta particles) and gamma-producing radionuclides empower 3D positron discharge tomography (PET) and single-photon emanation processed tomography (SPECT) imaging, separately. Subsequently, the radiopharmaceutical can be followed inside the body giving utilitarian data about explicit sub-atomic and cell processes in cancer relying upon the transporter particle, for example, bloodstream, digestion, receptor articulation, growth metastatic limit, aggravation, modified cell demise. Then again, radionuclides discharging beta particles (for example iodine-131, lutetium-177, yttrium-90), alpha-particles (for example actinium-225, astatine-221, bismuth-213, lead-212) or Auger electrons (for example iodine-125, iodine-123, indium-111, terbium-161, gallium-67), which are coupled to a disease focusing on the particle, can possibly convey a cytotoxic radiation portion to the malignant growth cells. This remedial procedure is called designated radionuclide treatment (TRT). TRT is a quickly developing field. Some new models

are the advancement of radiolabeled prostate-specific membrane antigen (PSMA) and the endorsement of  $[^{177}\text{Lu}]\text{Lu-DOTA-TATE}$  to treat neuroendocrine growths. In any case, research keeps on examining how to augment the advantage of radionuclide treatments that are successful and ok for every individual patient

## The potential advantages of nanoparticles in nuclear medicine

A 'nanomaterial' is characterized as a characteristic, coincidental, or made material with at least one outer aspect in the size range of 1 nm to 100 nm. In this size range, material properties become controllable. Subsequently, nanoparticles can emerge in a few shapes, for example, spheres, rods, discs, cubes, and cages. Moreover, as the size of the nanoparticles diminishes, their surface-region to-volume proportion is firmly expanding. Because of these particular properties, nanoparticles can offer a huge commitment to atomic medication. Initial, a significant benefit is the capability of a solitary nanoparticle to hold numerous radionuclides, accomplishing a lot higher payloads of radioactivity when contrasted with a traditional radiopharmaceutical agent that conveys only one or a couple radionuclides. Lucas, et al, determined in a Monte Carlo reproduction that nanoparticles containing various beta-producers (yttrium-90, lutetium-177, iodine-131, iodine-124, or rhenium-188) may convey a complete assimilated radiation portion of 60 Gy to a strong, non-small cell lung carcinoma model, which couldn't be accomplished by antibodies that were each formed to a solitary radionuclide. The quantity of radionuclides required per nanoparticle to accomplish 100 percent cancer control emphatically relies upon the actual properties of the radionuclide (the actual half-life, the radiation energy, and the infiltration profundity) and on the organic properties of the nanoparticles and the growth (cancer size, the intra-tumoral appropriation, the natural half-life and the take-up energy of the nanoparticles). Second, the prevalent hypothesis is that because of their little size, nanoparticles can productively extravasate through the holes between endothelial cells of the cracked and juvenile veins into the cancer mass. Moreover, the diminished degree of lymphatic seepage of the interstitial liquid inside the growth adds to nanoparticle cancer retention. This reasoning is known as the improved porousness and retention (EPR) impact and causes the aggregation and delayed maintenance of radiolabeled nanoparticles in the cancer tissue, expanding the growth radiation portion. In any case, it is essential to bring up that regardless of the EPR the impact is massively fruitful in preclinical creature models, the clinical adequacy and interpretation of disease nanomedicines stays poor, showing that the EPR peculiarity is less solid in human malignant growths. Third, the huge surface-region to-volume proportion of nanoparticles works with the functionalization of the nanoparticle surface with different malignant growth focusing on particles, which makes a multivalent impact, advancing an productive restricting to the cancer cells. Accordingly, the utilization of focused on nanoparticles could upgrade the conveyance of radioac-

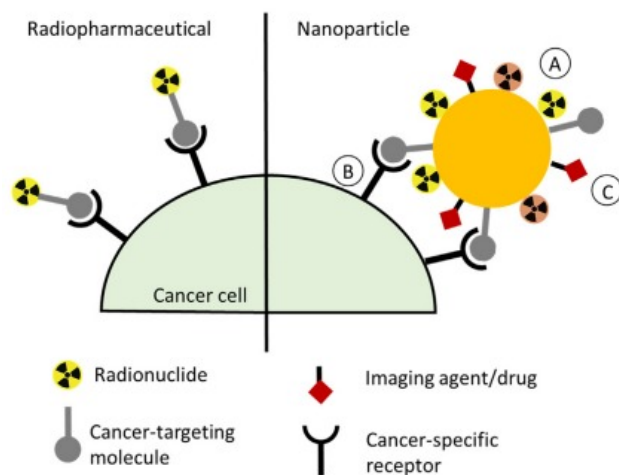


Figure 1: interaction of radiopharmaceutical alone with cancer cells as well as with the help of nanoparticles

tivity to cancer, which thus prompts superior remedial viability.

## Benefits of gold nanoparticles in cancer detection in therapy

**SURFACE PLASMON RESONANCE-** One of the main attributes of AuNPs includes the surface plasmon resonance (SPR), which happens when the occurrence light of a particular frequency causes a group and cognizant wavering of free surface electrons, bringing about the elimination of light and the age of hotness. Therefore, the SPR pinnacle of AuNPs makes them intriguing apparatuses for remedial applications, for example, photograph warm treatment (PTT) as well with respect to optical imaging applications, for example, photoacoustic (PA) imaging and surface-improved Raman dispersing. So, because of the transformation of light into heat, AuNPs can effectively instigate confined hyperthermia in the cancer tissue, making irreversible harm to the growth cells. Furthermore, the hotness creation causes a thermo-flexible extension of the AuNPs and the ensuing emanation of acoustic drifters, which can be tested by a transducer to develop photograph acoustic pictures.

**HIGH ATOMIC NUMBER OF GOLD-** AuNPs display a high nuclear number ( $Z = 79$ ), causing the particular retention of X-beam photons by the AuNPs contrasted with delicate tissue. Accordingly, bringing AuNPs into the body builds the X-beam lessening and consequently the difference of the X-beam-

based pictures. At present, iodine-based compounds are the most often utilized contrast specialists. Be that as it may, their quick renal freedom requires short imaging times and likely catheterization. 1.9 nm-sized AuNPs contain 250 gold molecules for each molecule and hence show a much lower osmolality and thickness at similar basic fixation as the iodine specialists. Moreover, the higher atomic load of the AuNPs causes a more slow blood leeway when contrasted with the iodine specialists, allowing longer imaging times after IV infusion. At long last, gold has a higher nuclear number and assimilation coefficient (79 and 5.16 cm<sup>2</sup>/g at 100 keV, individually) when contrasted with iodine (53 and 1.94 cm<sup>2</sup>/g at 100 keV, respectively). Likewise, the high nuclear number of AuNPs gives an advantage in radiotherapy. Without a doubt, the high nuclear number of AuNPs makes a few associations happen between the X-beam photons and the AuNPs. These incorporate the photoelectric impact, Compton dispersing, and pair creation, which discharge an explosion of optional electrons, upgrading the radiation portion affidavit inside the growth volume and hence expanding the viability of radiotherapy.

**BIOLOGICAL EFFECT OF GOLD NANOPARTICLE-** Significantly, other than their capacity to build the portion statement upon illumination, AuNPs can likewise cause natural impacts in malignant growth cells. For instance, AuNPs can catalyze the development of ROS and repress cell reinforcement safeguard frameworks. Thus, oxidative pressure can cause mitochondrial brokenness, DNA harm, autophagy, apoptosis, and G2/M cell cycle capture, which is the most radiosensitive cell cycle stage. Then again, AuNPs could likewise repress DNA fix instruments or weaken lysosomes, which expands the overflow of misfolded and accumulated proteins, causing ER stress. Because of these natural impacts of AuNPs, disease cells could have a decreased ability to answer sufficiently to ionizing radiation and are in this way more delicate to radiotherapy. Taking everything into account, radiolabeled AuNPs don't just can further develop atomic medication imaging and treatment via conveying a higher payload of radionuclides and gathering in the growth tissue, yet additionally, permit the blend of various optical imaging modalities to further develop disease recognition and follow-up. Then again, joining various therapy modalities, for example, focused on radionuclide treatment, photothermal treatment, and (natural, compound, and physical) radiosensitization, can synergize the adequacy of the anticancer treatment to battle radio-safe or potentially chemo-safe disease cells.

## Radiolabeling of gold nanoparticles

A steady relationship between the radionuclide and the nanoparticle is fundamental for the fruitful execution of radiolabeled nanoparticles in malignant growth analysis and treatment. Loss of the radionuclide can bring about its collection in non-designated tissues. A regularly utilized technique is the utilization of bifunctional chelators, which firmly have complex radiometals. The

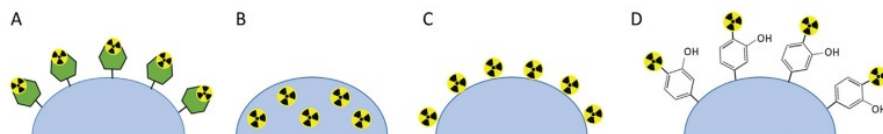


Figure 2: Radiolabeling of nanoparticles by (A) chelation, (B) incorporation, (C) chemisorption and (D) covalent binding.

bifunctional chelators can be straightforwardly joined to the AuNPs by means of thiolated linkers, for instance, comprising out of a glycine-glycine succession going about as spacer followed by a cysteine buildup giving a functioning thiol bunch, which connects with the AuNP surface likewise, the bifunctional chelators can be by implication connected to the AuNPs through a covalent attach to the nanoparticle covering or to the vector atom. In the improvement of radiopharmaceuticals, a fruitful bifunctional chelator limits the separation of the radionuclide from the chelator in vivo. This relies upon the thermodynamic strength and kinetic inertness of the bifunctional chelator. The thermodynamic stability reflects the direction of the dissociation reaction, while the kinetic inertness reflects the rate of the dissociation reaction. Two well-known bifunctional chelators are diethylenetriaminepentaacetic acid (DTPA) and dodecane tetra acetic acid (DOTA).

Following organization in vivo, the pharmacokinetics and biodistribution profile of designated AuNP-based radiopharmaceuticals, conveying various focusing on particles, significantly contrast from the monomeric radiopharmaceuticals lacking AuNPs. For example, the radiolabeled low-sub-atomic weight monomers are cleared from the blood pool shortly after intravenous (IV) administration. The blood purification of the little monomeric radiotracers is trailed by early discharge, principally by means of the kidneys and less significantly through the hepatobiliary pathway, 0-20 h post-infusion. Not at all like little atoms, high sub-atomic weight focusing on specialists, like antibodies, are not discharged through the renal framework, yet aggregate in the liver. The main distinction in biodistribution design is the fundamentally higher take-up of the colloidal radiolabeled AuNP analogs in the liver, spleen and lungs, contrasted with the low- and high-atomic weight monomeric frameworks. Discharge of the radiolabeled AuNPs can happen through both the renal framework and the hepatobiliary framework, contingent upon their size

## Assessment of gold nanoparticles in nuclear medicine

**TUMOR UPTAKE, RETENTION, AND DISTRIBUTION** -The innate AuNP qualities, like their size, shape, and covering are deciding elements that can influence the AuNP pharmacokinetics, biodistribution, and cancer take-up. Conse-

quently, these properties must be painstakingly tuned to expand the cancer take-up, the growth to foundation proportion (T/B), and in this way the adequacy of radiolabeled AuNPs as indicative and remedial nano-radiopharmaceuticals. For this reason, SPECT, PET, and CT are helpful imaging devices to all the more likely comprehend the in vivo conduct of radiolabeled AuNPs progressively. Likewise, inductively coupled plasma-mass spectrometry (ICP-MS), gamma-counting and optical imaging, for example, Raman dispersing imaging, Cerenkov radiance imaging, photoacoustic imaging, and fluorescence imaging can be utilized to supplement the atomic imaging and to confirm the amount of AuNPs in the significant organs and in the growth.

**IMAGING-** An early analysis of disease is regularly connected with a superior visualization. Along these lines, close to SPECT and PET imaging, the customary, painless imaging frameworks, for example, CT and MRI are fundamental in the facility. Gold nanoparticles can possibly work on the differentiation of CT pictures on account of their high nuclear number and high X-beam constriction. MRI is likewise a typical clinical imaging modality offering physical data in high-spatial goal, with a high differentiation in delicate tissue. To take advantage of AuNPs as a differentiation specialist for MRI, they should be complexed with MRI contrast materials. For example, multicomponent nanoparticles have been created by encompassing a magnetic center of iron oxide with a gold shell, or by coupling iron-oxide nanoparticles to AuNPs. The radiolabeling of AuNPs empowers the improvement of PET-CT and SPECT-CT that is dual modality imaging. For example, focused on dendrimer-captured AuNPs and polyethylenimine-ensnared AuNPs, radiolabeled with technetium-99m or with iodine-131, improve the CT contrast on one hand and empower SPECT imaging then again of sentinel lymph hubs as well as of glioma cells, fibrosarcoma cells, cervical disease cells and hepatocellular carcinoma cells. The X-beam lessening property of the AuNPs is surpassing that of Omnipaque, a clinically utilized iodine-based CT contrast specialist. Besides, the expansion in SPECT(-CT) signal force is connected with the centralization of gold and the radionuclide in the cancer cells. Thus, the SPECT(-CT) imaging contrast upgrade altogether further develops while malignant growth focusing on tests, for example, chlorotoxin, chlorotoxin-like peptides, duramycin, cRGD, EGF, folic corrosive or pH-responsive moieties are connected to the nanocarriers when contrasted with the untargeted analogs, negative malignant growth cell models or impeded disease cell receptors. For therapeutic purposes, the goal of radiolabeled AuNPs is to deliver a lethal radiation dose to the tumor site, while minimizing the radiation damage to healthy tissue. The effectiveness of radiolabeled AuNPs for TRT and as multimodal therapeutic agents has been investigated in vitro and in vivo.

## Conclusion

in this paper we saw in detail about nanoparticles and its advantages in the field of nuclear medicine, we gave an overview on the radiolabeling processes of AuNPs and the potential of radiolabeled AuNPs. We saw that designated, radiolabeled AuNPs enhance the tumor uptake and retention, causing a superior cancer control contrasted with their radiopharmaceutical analogs without AuNPs. Moreover, radiolabeled AuNPs empower the utilization of multimodal imaging stages for the perception of their maximal tumor uptake to initiate photothermal therapy, to increase the effectiveness of external beam radiotherapy. the delivery of radionuclides, radiolabeled AuNPs also have the potential to carry chemo therapeutic drugs, mediate photothermal ablation and radiosensitize cancer cells, which makes them valuable tools to overcome chemoresistance cancer cells.

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