An optimization study for preclinical x-ray imaging of gold nanoparticles using GATE simulations

Rouchota Maritina[1], Loudos George[2], Papadimitroulas Panagiotis[3], Kagadis George[1]

[1]University of Patras, Rion, Patras, Greece

[2]Technological Educational Institute of Athens, Ag. Spiridonos 28, Egaleo, Athens, Greece

[3]BET Solutions, R&D Department, Alexandras Av. 116, Athens, Greece

Purpose: Being able to visualize Gold Nanoparticles (GNPs) through X-Ray and CT imaging is very important in Medical Imaging as GNPs can prove to be a contrast agent with better properties than iodine for the visualization of the circulatory system. Moreover, the radiolabeling process of the NPs – a process needed in order to follow the targeted radiopharmaceutical root - may be accurate but it might modify their nature and properties, whereas x-rays do not add to complexity or modification. For these studies usually a large number of animals is needed to test appropriate concentration of GNPs that will provide adequate contrast for each x-ray system. This number can be significantly reduced by optimizing the imaging protocols to be implemented, through this simulation platform.

Materials & Methods:

The developed simulation platform consists of the following basic steps (Fig 1):

1. The system is simulated by copying the exact experimental conditions – x-ray beam characteristics, detector specifications, experimental geometry, phantoms. The system simulation is validated by imaging iodine solutions and comparing with the experimental results (Fig 2A)

2. NP solutions are simulated, based on two main points: That in CT/X-ray the direct visualization of NPs is not possible, only density variations are visible (LeBrun, 2016) and that the geometry and size of the NPs strongly affect their biodistribution, but they do not affect the image contrast (Nohyun Lee, 2013). So NP solutions are simulated as homogenous solutions of different densities. The validation of the NPs imaging properties is performed by imaging different solutions in a phantom and comparing experimental and simulated results (Fig 2B).

3. The bio-distribution of the NPs under study are imported as density variations in MOBY organs, based on the administered NP quantity and their given PW% concentration in each tissue.

4. After running the simulation x-ray images are exported, visualizing the bio-distribution of the GNPs.
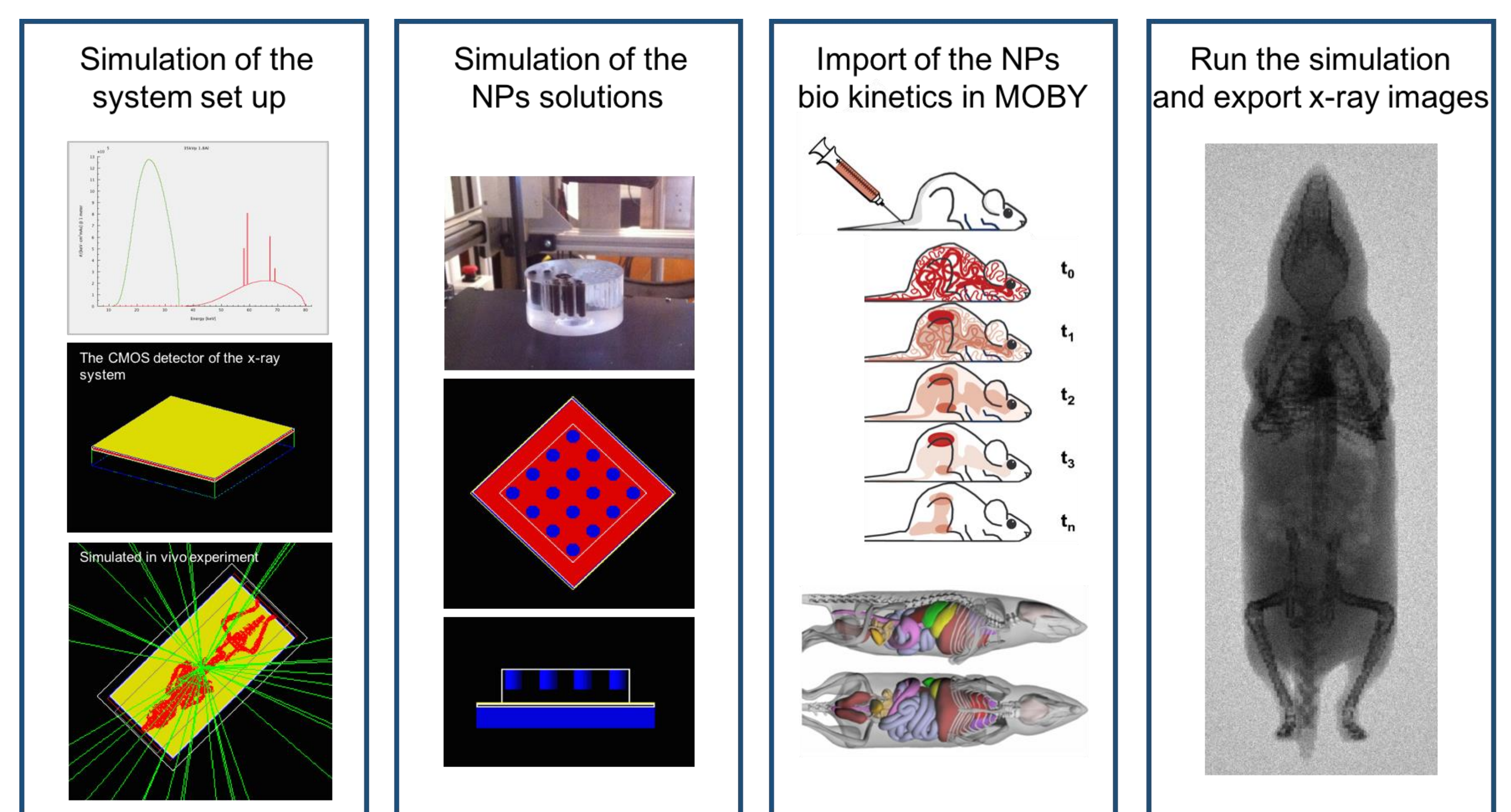

Figure 1: The basic steps of the simulation platform developed for NPs x-ray imaging.
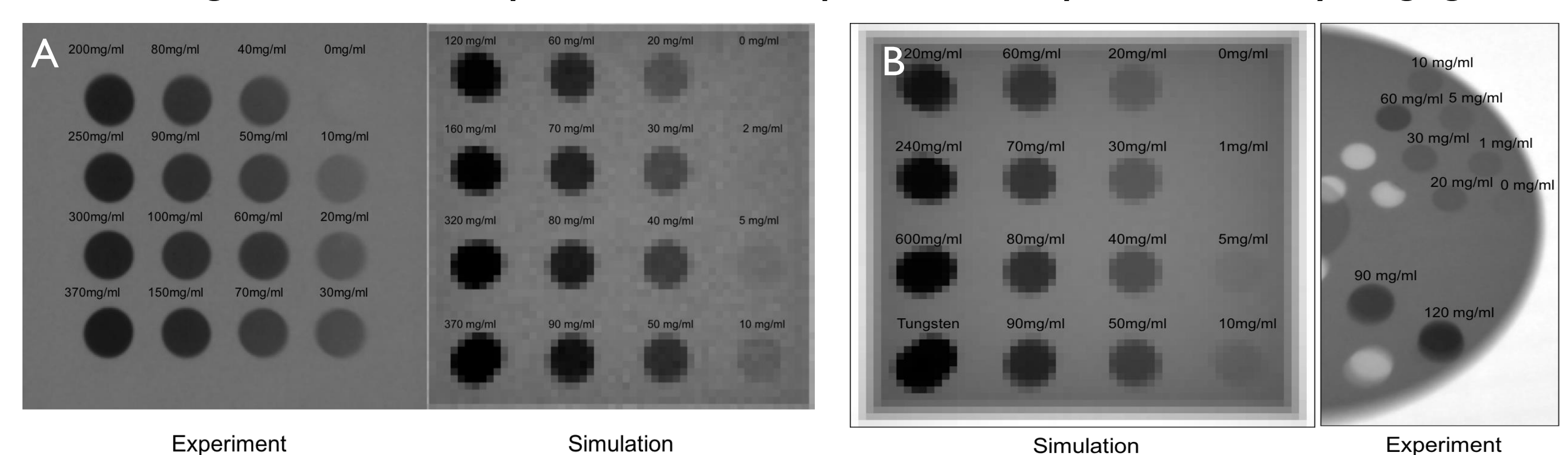

Figure 2: Validation of the system with iodine solutions (A) and of the NPs imaging properties (B) by comparing experimental and simulation imaging results.

Results: Bio-distributions of several GNPs types, already published in literature, were used and for each bio-distribution and specific time points the appropriate x-ray images were exported (Fig 3). The images are exported for an x-ray system used in our laboratory (35 kVp, 0.5 mA, 0.1 sec exposure time). The same can be done for any X-ray. Administered concentrations of GNPs and specific PW% concentrations in tissues can be checked as far as resulting image contrast is concerned. This way, for the bio-distributions that do not produce the desired contrast, either in vivo studies are not recommended or a higher initial concentration is needed to be administered.
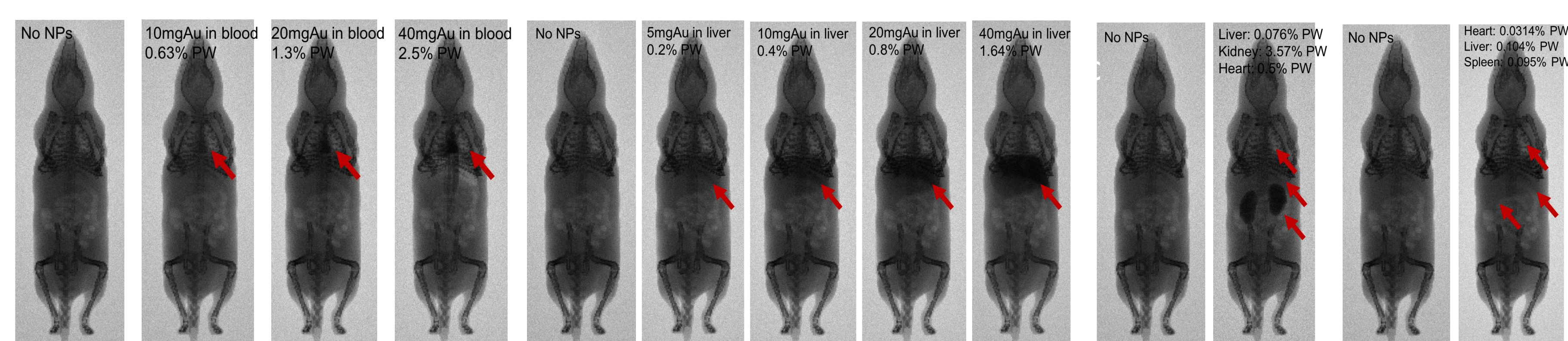

Figure 3: A) Pre and post GNPs administration when full accumulation in blood is assumed. B) The same for full liver accumulation. C) Bio distribution of GNPs by J. Hainfeld et al (2004), 5min p.i. D) Bio distribution of GNPs by W. D. James et (2007), 4hrs p.i..

Conclusions: A simulation platform has been developed and validated for X-ray imaging studies with GNPs. This platform allows for a quick check, whether a certain administered GNP concentration with a given bio distribution can produce the desired contrast, at any given x-ray system. This provides the possibility of optimizing imaging protocols and reducing the number of animals needed for an in vivo X-ray imaging study with GNPs.