X-RAY FLUORESCENCE CT FOR IMAGING OF GOLD NANOPARTICLES AND CISPLATIN

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INTRODUCTION

Conventional x-ray CT imaging performed with photon-integrating detectors offers high spatial resolution and fast scanning times. Currently, CT lacks behind other imaging modalities in providing **molecular contrast** due to its limited sensitivity. Probes containing high atomic number elements can be potentially imaged at low concentrations using x-ray CT scanners equipped with **photon-counting detectors** with **x-ray fluorescence CT** (XFCT)[1]. In this work, a CT/XFCT x-ray system for imaging of **gold nanoparticles (Au)** and **Cisplatin (Pt)** was simulated and thoroughly investigated using the **Monte Carlo** method.

METHODS AND MATERIALS

Monte Carlo model

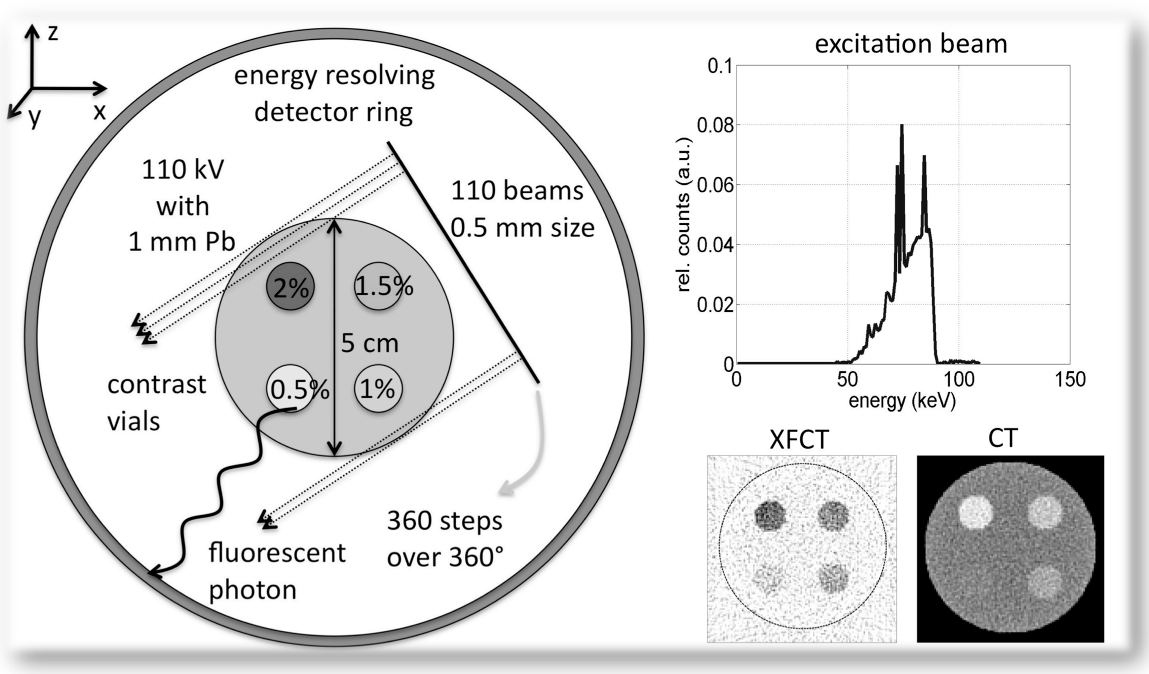

Figure 1: Simulation setup of x-ray fluorescence and transmission CT imaging. The x-ray excitation source was a 110 kV photon beam (spectrum shown on the right). Examples XFCT and transmission CT images simulated in the EGSnrc/DOSXYZnrc code are also presented.

Detector arrangement

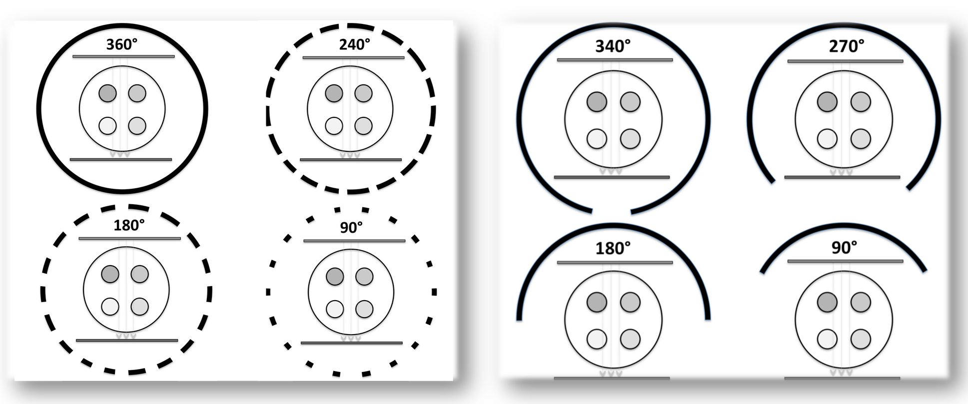

Figure 2: Simulation geometry for the study of the number of detectors (left) and Compton scatter reduction (right).

Phantoms

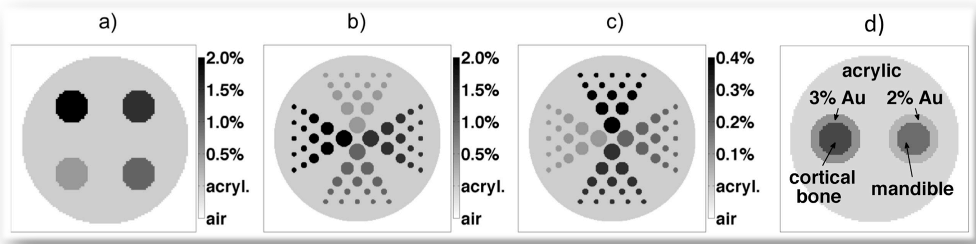

Figure 3: The low-resolution (a), high-resolution high-concentration (b), high-resolution low-concentration (c), and bone (d) phantoms used for investigation of image quality. Phantoms (a), (b), and (c) were filled with both Au and Pt.

Image reconstruction

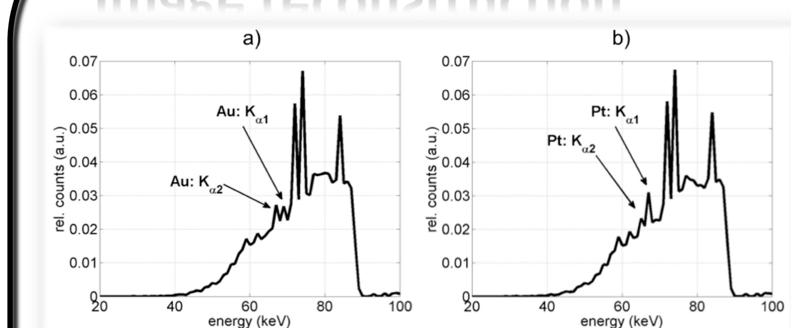

Figure 4: Energy spectrum for a single sinogram point of the low-resolution phantom loaded with gold (a) and platinum (b) imaged with 0.1 mGy.

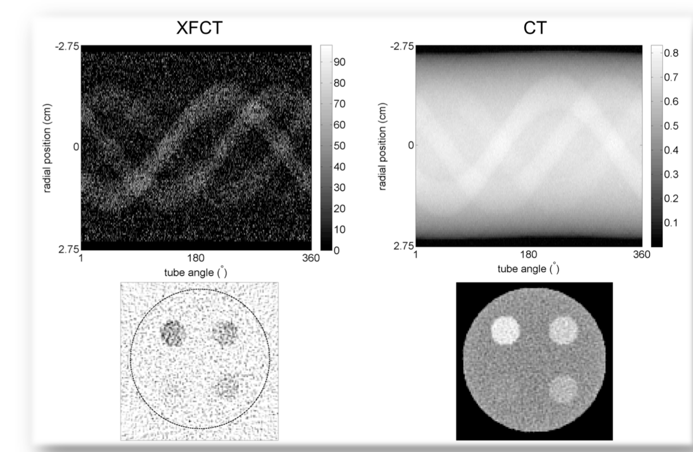

Figure 5: Example sinograms (top) and reconstructed CT images (bottom) for XFCT (left) and transmission CT (right) for 0.1 mGy.

RESULTS

Reconstructed XFCT and CT images

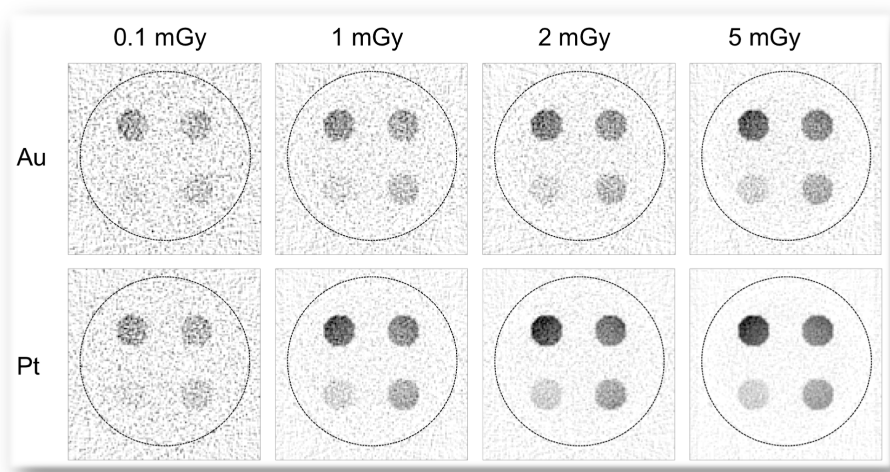

Figure 6: XFCT images of the low-resolution phantom loaded with gold (top) and platinum (bottom) as a function of imaging dose.

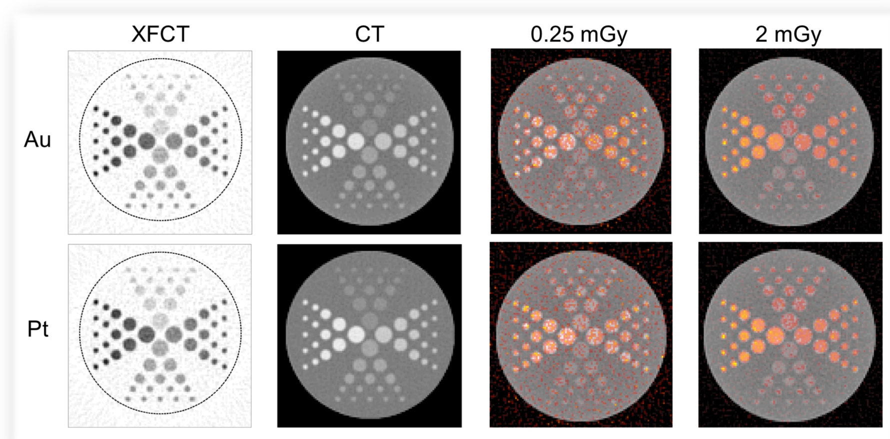

Figure 7: XFCT, CT and overlay XFCT/CF images of the high-resolution high-concentration phantom with gold (top) and platinum (bottom) acquired with a full detector ring. XFCT images (first column) and conventional transmission CT images (second column) for imaging dose of 2 mGy are presented.

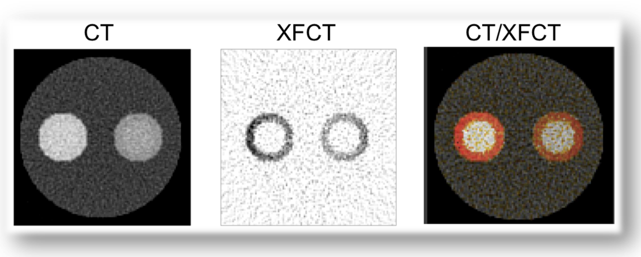

Figure 8: CT, XFCT and overlay CT/XFCT images of the bone phantom depicted in Figure 3. Note that gold is not visible in the CT image alone.

Reconstructed CNR of XFCT images as a function of imaging parameters/system

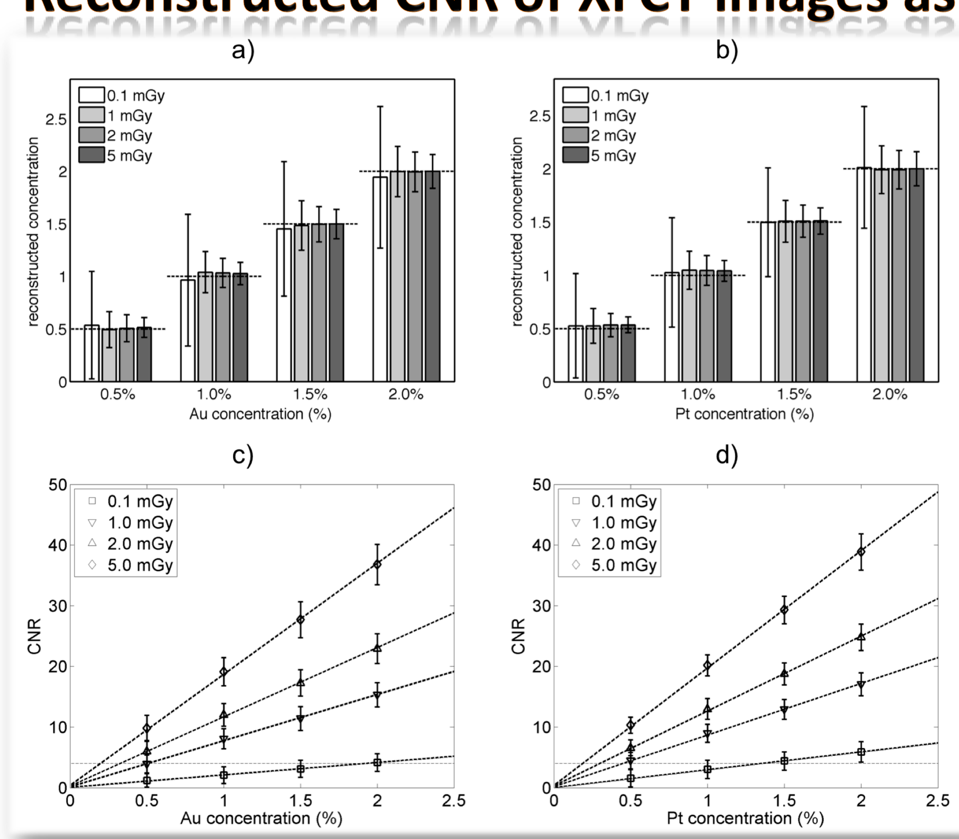

Figure 9: Reconstructed concentration (a,b) and CNR (c,d) as a function of contrast concentration and imaging dose for gold (a,c) and platinum (b,d) based on simulations of the low-resolution phantom imaged with 2 mGy dose.

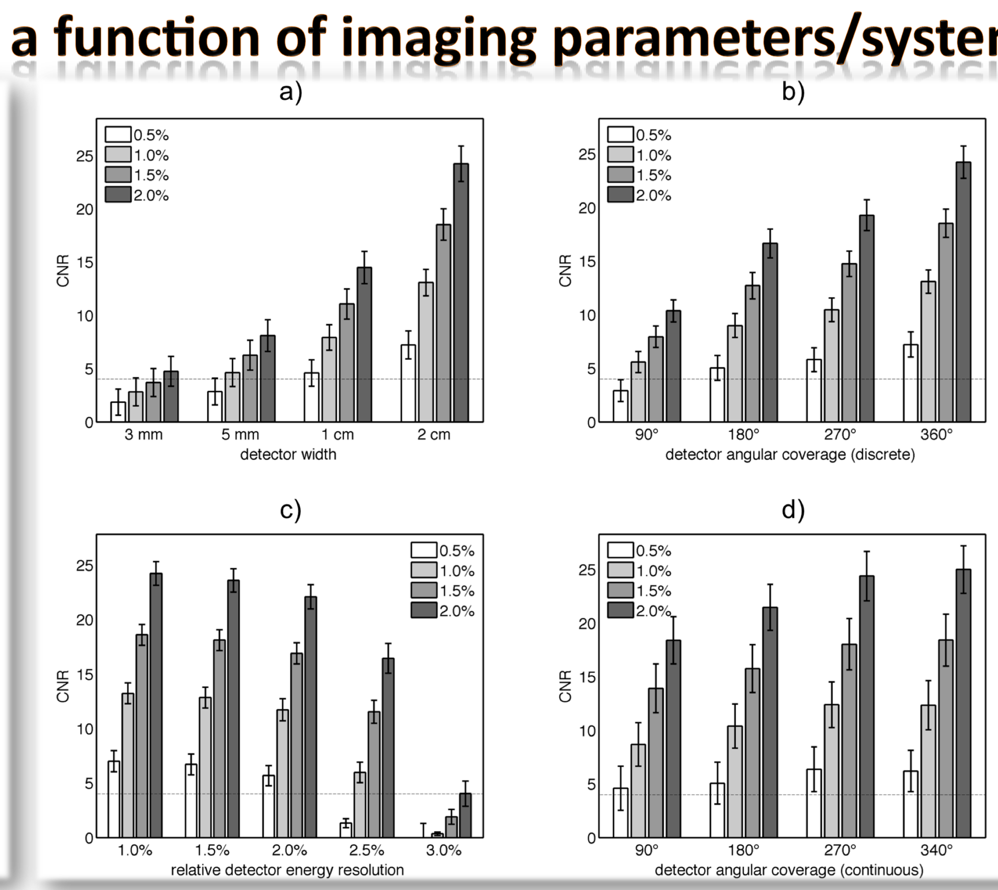

Figure 10: CNR for 0.5%-2.0% concentrations of platinum as a function of detector width (a), discrete detector angular coverage (b, Figure 2 left), detector energy resolution (c), and continuous detector angular coverage (d, Figure 2 right).

XFCT and CT comparison

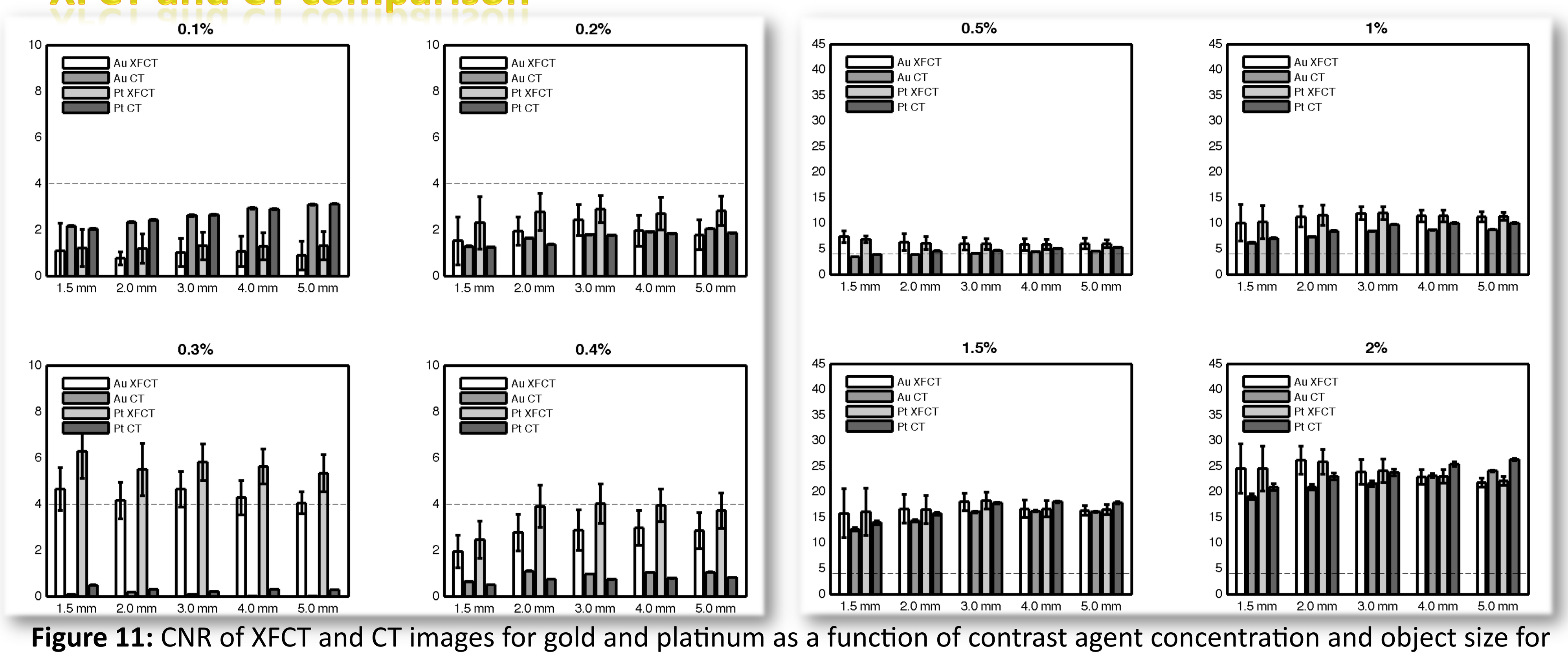

Figure 11: CNR of XFCT and CT images for gold and platinum as a function of contrast agent concentration and object size for concentration of 0.1% to 2.0 %. Imaging dose is 2 mGy. The sensitivity of XFCT is higher than CT for most cases.

CONCLUSIONS

With the recent advances in photon-counting detector technology, XFCT may become a competing molecular imaging modality for probes containing high-*Z* elements. Simultaneous CT/XFCT imaging has the potential to become a useful tool for *in-vivo* imaging, as it produces CT images with combined anatomical and molecular information.

ACKNOWLEDGEMENTS

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REFERENCES

[1] S.-K. Cheong, B. L. Jones, A. K. Siddiqi, F. Liu, N. Manohar and S. H. Cho, "X-ray fluorescence computed tomography (XFCT) imaging of gold nanoparticle-loaded objects using 110 kVp x-rays," Phys Med Biol **55**, 647-662 (2010).

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