Compton scatter in x-ray fluorescence CT imaging

Innovation/Impact: To design and optimize an x-ray fluorescence CT imaging systems for high-sensitivity molecular imaging of gold and platinum by means of Monte Carlo simulations.

Figure 1: Simulation geometry of XFCT and CT imaging using 1st generation CT scanning with the variations of the detector geometry angular coverage. Full ring geometry was also considered.

Figure 2: Simulated XFCT (top left) and CT (bottom left) sinograms for a phantom with gold and contrast-to-noise ratio (CNR) for a gold and platinum for a full detector ring.

Figure 3: Fluorescence spectra (red lines) and the Compton scatter contribution (black lines) for detector coverage of 340°, 270°, 180°, and 90° (left). For the highest counts of fluorescence x-rays, the fluorescence photons are superimposed on a flat portion of the Compton scatter contribution. Reconstructed XFCT images with gold (right).
Figure 4: Contrast-to-noise ratio (CNR) as a function of detector angular coverage for gold (left) and platinum (right) for an imaging dose of 2 mGy. The position of the fluorescence peaks with respect to the Compton scatter contribution affects the extracted number of fluorescence x-ray from the data. Whereas for gold, the maximum CNR of 5.9 occurs for the 180° geometry, the maximum platinum CNR of 6.2 is observed for the 340° geometry. For imaging dose of 2 mGy, the imaging sensitivity is 0.28% and 0.25% for gold and platinum, respectively. In Figure 2 with full ring, the sensitivity is 0.42% and 0.40%, respectively.

![Figure 4: Contrast-to-noise ratio (CNR) as a function of detector angular coverage for gold (left) and platinum (right) for an imaging dose of 2 mGy. The position of the fluorescence peaks with respect to the Compton scatter contribution affects the extracted number of fluorescence x-ray from the data. Whereas for gold, the maximum CNR of 5.9 occurs for the 180° geometry, the maximum platinum CNR of 6.2 is observed for the 340° geometry. For imaging dose of 2 mGy, the imaging sensitivity is 0.28% and 0.25% for gold and platinum, respectively. In Figure 2 with full ring, the sensitivity is 0.42% and 0.40%, respectively.](image)

Figure 5: Reconstructed images of another phantom with gold (top) and platinum (bottom) at 2.0%, 1.5%, 1.0%, and 0.5% concentrations 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. Overlay XFCT and CT images for imaging doses of 0.25 mGy and 2 mGy demonstrating how anatomical x-ray CT imaging can be enhanced by combining it with molecular information.

![Figure 5: Reconstructed images of another phantom with gold (top) and platinum (bottom) at 2.0%, 1.5%, 1.0%, and 0.5% concentrations 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. Overlay XFCT and CT images for imaging doses of 0.25 mGy and 2 mGy demonstrating how anatomical x-ray CT imaging can be enhanced by combining it with molecular information.](image)

**Conclusions:** The MC study demonstrates that the angularly dependent Compton scatter contamination of x-ray fluorescence data affects the sensitivity of XFCT imaging and should be taken into account in the design of the imaging device.