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Titles: Radiation Dose Optimisation for Pre-Clinical Examinations with MARS-CT
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Introduction:
Recent advances in CT (computed tomography) technology has brought to the forefront a new imaging modality that provides an accurate material decomposition of images through the use of CERN Medipix detector technology. In addition, MARS CT technology promises to significantly reduce doses received during scanning, compared to conventional CT imaging systems.
CT assessment measurements are made using phantoms, typically made of low density and low atomic number materials, to simulate human body parts. An example is the CatPhan phantom (https://www.phantomlab.com/catphan-500). For conventional CT systems, measuring the signal to noise ratio (SNR) is one of the standard assessments of image quality. Another important CT assessment is radiation dose measurement during the acquisition scan, which would be done with the determination of the computed tomography dose index (CTDI) in a standard CT quality assurance procedure. Both image quality and radiation dose are directly linked with each other ie. the higher the radiation dose, the greater the image quality. However, due to different detector technology, a standard of assessment unique to MARS-CT had to be established. This is achieved by measuring the system's ability to differentiate and quantify different materials. This is called material decomposition (MD) identification success.

Aim:
The aim of my project was to assess image quality through parameters such as spatial resolution and signal to noise ratio, evaluate x-ray dose and assess material identification errors at various dose levels to provide an optimal dose reduction while maintaining image quality and correct material identification in MARS spectral CT system.

Impact:
MARS technology provides the means to differentiate and quantify multiple biomarkers in the target tissue at the same scan with reduced radiation dose. However, little research has been done to investigate the effect of x-ray dose on the energy resolving capability of spectral CT system.

Method:
Imaging quality control methodologies were measured in custom-built phantoms that were adapted from standard phantoms designed for human examination to micro-CT. Measurements included image noise, signal to noise ratio and high contrast spatial resolution. A spectral phantom containing gadolinium (1, 2, 4, 8 mg/ml) and hydroxyapatite (0, 54.3, 104.3, 211.7, 402.3, 808.5 mg/ml), water and vegetable oil was used to measure material identification errors. Radiation dose measurements were performed with CERN and Lausanne University Hospital who provided thermoluminescent dosimeters (TLDs). The measurements were performed using a MARS spectral scanner with a 0.375mm brass filtered poly-energetic x-ray source operated at 118 kVp and a CZT Medipix3RX camera. Four imaging protocols were used: with a fixed tube voltage of 118 kVp and four different exposure settings ie. 24µA, 34µA, 44µA, and 54µA.

Results:
It was found that image quality assessment standards (image noise, signal to noise ratio and high contrast spatial resolution) did not improve significantly as the radiation was increased. These results were counterintuitive, however are extremely important to know for dose reduction.

MD identification success for higher concentrations of Gd and HA (4 and 8 mg/mL of Gd and 104.3 mg/mL and greater of HA) were between 90% and 100% for all exposure settings. For higher concentrations, 24µA protocol provides the optimal ratio between image quality and dose.
The lower concentrations (Gd 1, Gd, 2 and HA 50 mg/mL) suffered from MD identification errors. Improvement of MD identification success was observed as the exposure setting was increased. However, improvement was not significant compared to the increase in radiation dose, reinforcing the justification that 24 µA was the most appropriate scan protocol.
Applying the newly found optimised protocol, a scan of a mouse with Gd injected and with TLDs inserted at certain positions in the body was performed which resulted in material decomposed "colour" CT images with adequate image quality. Gd was visible as green, where it accumulated in the bladder and kidneys and TLDs were visible as orange. This experiment provided the first organ dose measurement for small animals with MARS-CT single chip.

Conclusion:
By combining the results of all measurement's, it was found that using the lowest x-ray tube current; 24 µA, would not significantly affect image quality, at the same time, would dramatically lower radiation doses to the patient, in comparison of higher tube current protocols (54 µA). 24 µA was established as the optimal protocol due to providing a balance between adequate image quality, comparable to that of higher tube currents and radiation dose.