Dose saving in iodine quantitative imaging with photon-counting CT at low-tube voltage

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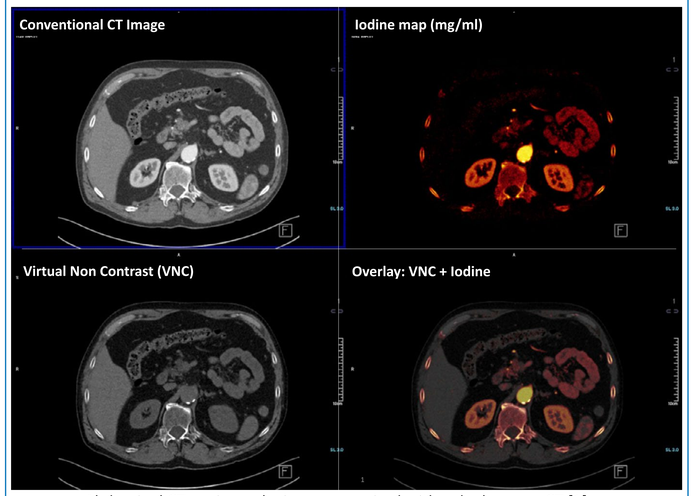
CLINICAL CONTEXT

• Spectral CT imaging is a clinical modality that takes advantage of multi-energy CT acquisition to generate spectral images. In the case of a contrast-enhanced scan, spectral images such as iodine concentration maps, virtual non-contrast-enhanced can be generated to improve diagnostics:

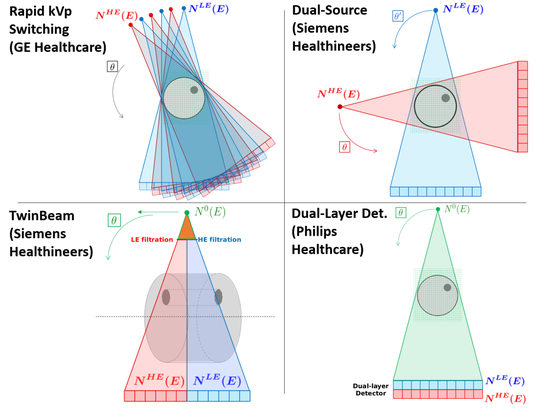


Abdominal CT angiography images acquired with a dual-energy CT [1].

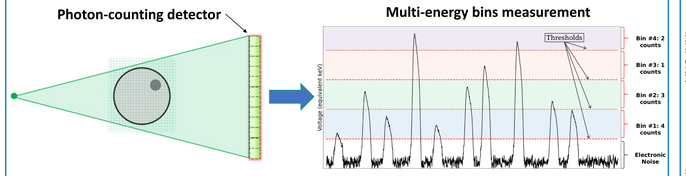
• CT acquisitions are generally performed for adult patients at 120 kV. With the emergence of noise reduction techniques and photon-counting detector (PCD), it has been demonstrated that lower tube voltages can reduce the dose while preserving image quality in conventional CT images [2].

DUAL-ENERGY CT LIMITATION

• Currently, multi-energy (or spectral) CT is performed with a dual-energy (DE) measurement and energy integrating detectors. However, DE-CT configurations limit the minimal voltage to 120 kV in spectral mode, preventing production spectral images in low-voltage dose-saving protocols.



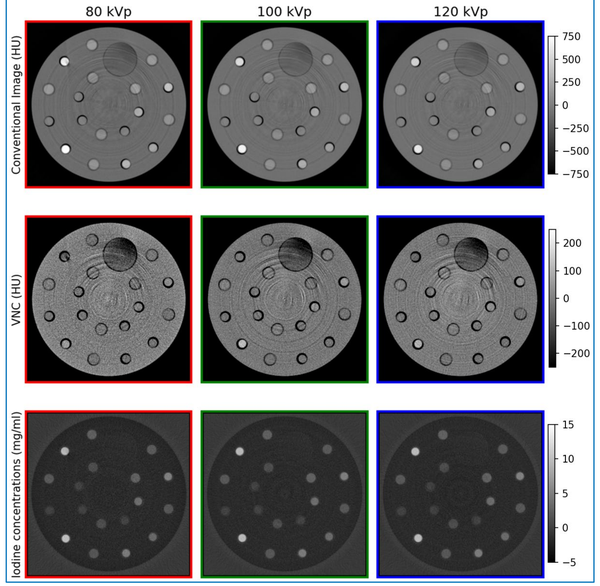
• On the other hand, CT scanners equipped with a PCD can within the same acquisition reconstruct mono- and multi-energy images



EXPERIMENTAL SETUP

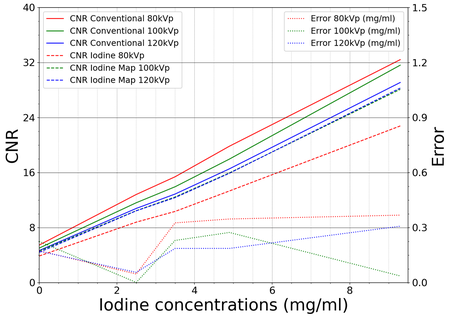
• Tubes filled with iodine contrast agent at different concentrations (2.5, 3.5, 4.9 and 9.3 mg/ml) were placed in a 10-cm diameter polyethylene phantom, to reproduce the contrast of an angiography CT clinical task. Acquisitions were performed with a PCD-CT system featuring a prototype CZT detector with a 330-µm pixel pitch providing six energy bins (35/41/47/53/59/65 keV). The x-ray source current was adapted to 1.04 mA, 0.69 mA and 0.5 mA to provide a constant dose at 80 kV, 100 kV and 120 kV, respectively.

• A monoenergetic image and a water/iodine material decomposition (MD) maps were reconstructed for each tube voltage. For the MD, a semi-empirical forward model was defined and tuned through calibration measurements. The calibration basis was composed of 20 combinations of known water lengths and iodine concentrations. The model was used as an input for a projection-based MD algorithm:



RESULTS

• The error on iodine concentrations was evaluated and the vial contrast-to-noise ratios (CNRs) were measured in the monoenergetic images and iodine maps.



• The mean concentration error was: 0.25 mg/ml at 80 kV, 0.15 mg/ml at 100 kV and 0.18 mg/ml at 120 kV. Compared to the 120 kV acquisition, a 8.1% and 17.4% CNR increase were measured at 100 kV and 80 kV, respectively. In the iodine map, the CNR improved by 0.9% at 100 kV and reduced by 16% at 80 kV with respect to the 120 kV iodine map.

• At a constant radiation dose, the CNR was improved with the reduction of the tube voltage. PCD-CT can provide accurate iodine spectral images at 80 and 100 kV with an error inferior to 1 mg/ml. However, the CNR in the spectral iodine map was maintained at 100 kV but reduced at 80 kV compared to the 120 kV iodine map.

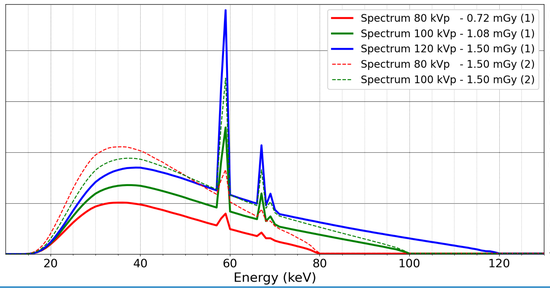
CONCLUSIONS

• PCD-CT can provide accurate iodine spectral images at 80 and 100 kV tube voltages while improving CNR in the monoenergetic image. However, care should be taken in selected the appropriate tube current, as too low tube voltages can increase the noise in PCD-CT spectral images. This would enable to provide accurate iodine quantification in low-voltage dose-saving protocols, which is not possible with current clinical DE-CTs.

PURPOSE

• The goal of this work was to investigate whether PCD-CT can perform accurate spectral imaging with a single low-energy spectrum at 80 or 100 kV, resulting in dose reduction. Specifically, we have quantified iodine concentrations for images acquired at 80, 100 and 120 kV.

• For this purpose, three voltages were investigated: 80, 100 and 120 kVp and compared at constant dose with a table-top PCD system. An equivalent dose was reached by modulating the exposure time and current.



(1) The indicated value is the air kerma computed with SpekPy [3] for 1 mAs exposure or with the exposure leading to the same dose (2)

REFERENCES

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[3] Poludniowski G *et al.*, Technical Note: SpekPy v2.0—a software toolkit for modeling x-ray tube spectra. Med. Phys., 2021.