

Deep-QA: a deep quality assurance network for AI in CT applications

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Introduction: Applications of AI in CT

Radiation dose reduction

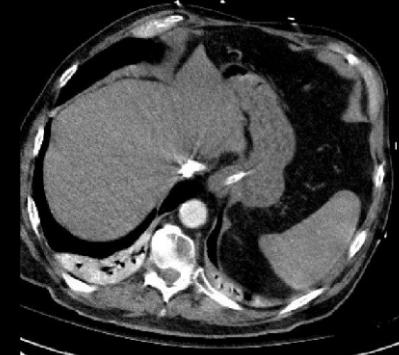


Low-dose FBP

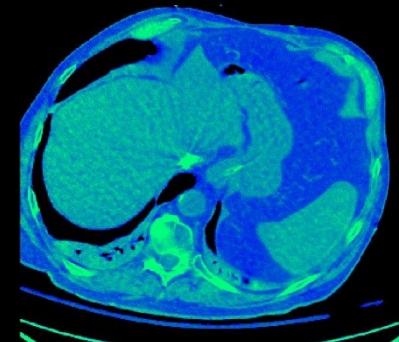


Denoised

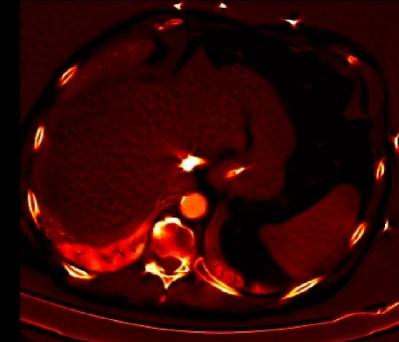
Material image estimation



Single-kV CT

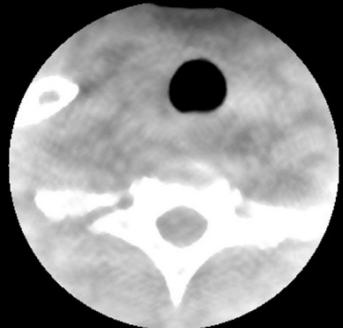


Estimated water
image

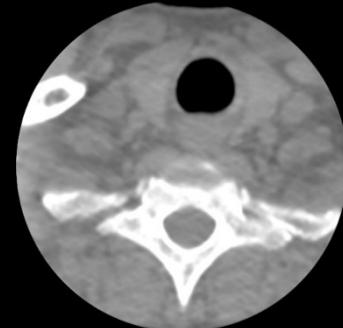


Estimated iodine
image

Detruncation



Extrapolation-based



iCT-Net

Benchmark AI Performance: Conventional Wisdom

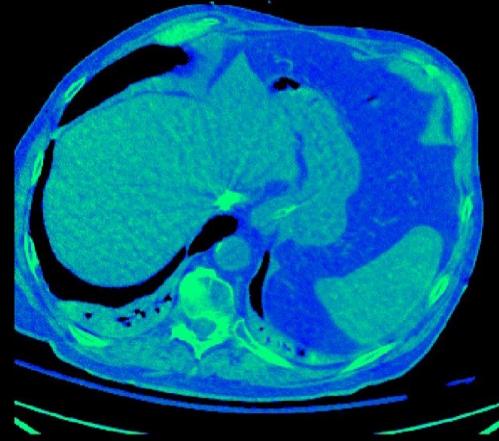


- Compute the errors of AI generated results with respect to reference standards

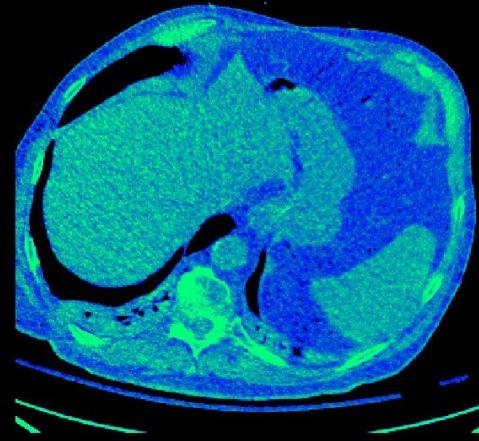
Benchmark AI Performance: Conventional Wisdom



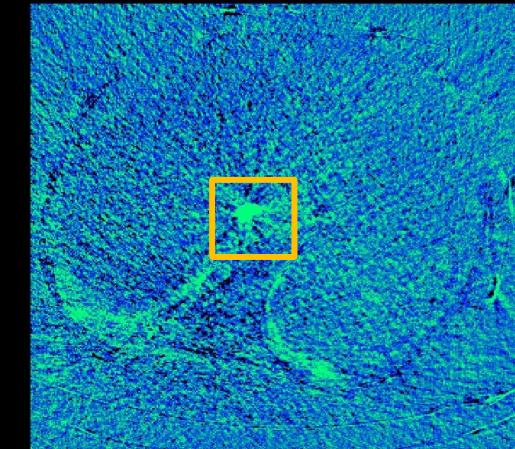
AI-based Estimation
Results



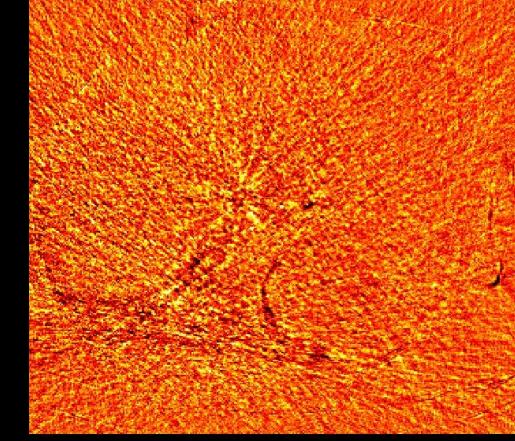
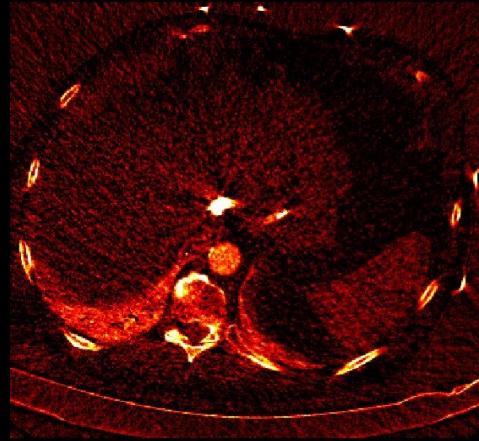
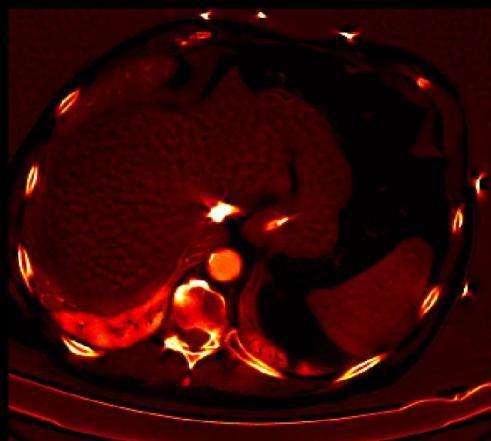
Reference Standard
Images



Estimation Errors



Water basis image

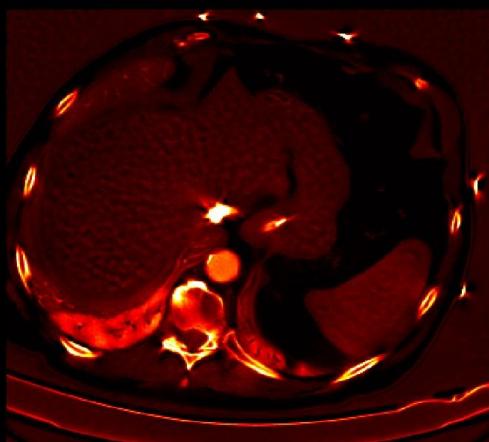
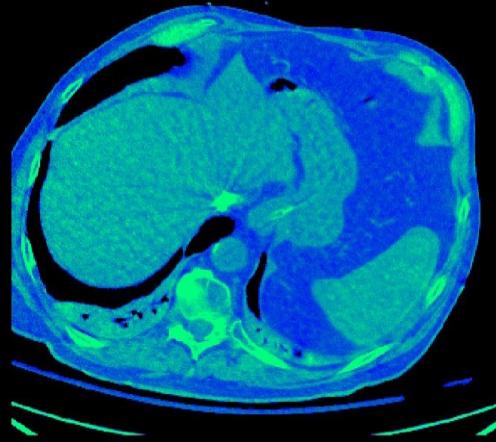


Iodine basis image

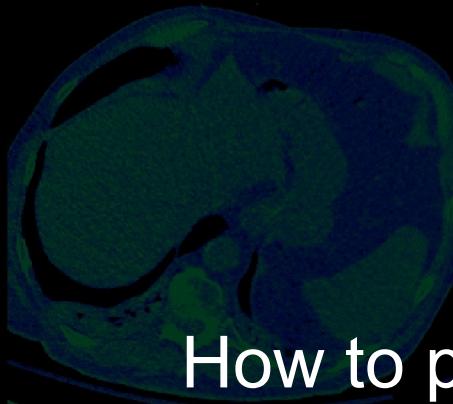
Challenge: Unavailability of Reference Standard Images for Individual Patients



AI-based Estimation Results

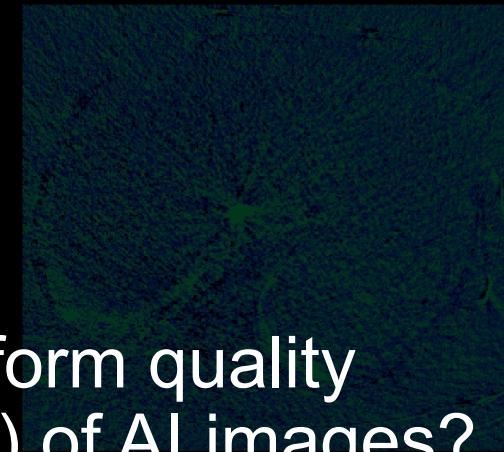


Reference Standard Images



How to perform quality assurance (QA) of AI images?

Estimation Errors



Water basis image

Iodine basis image

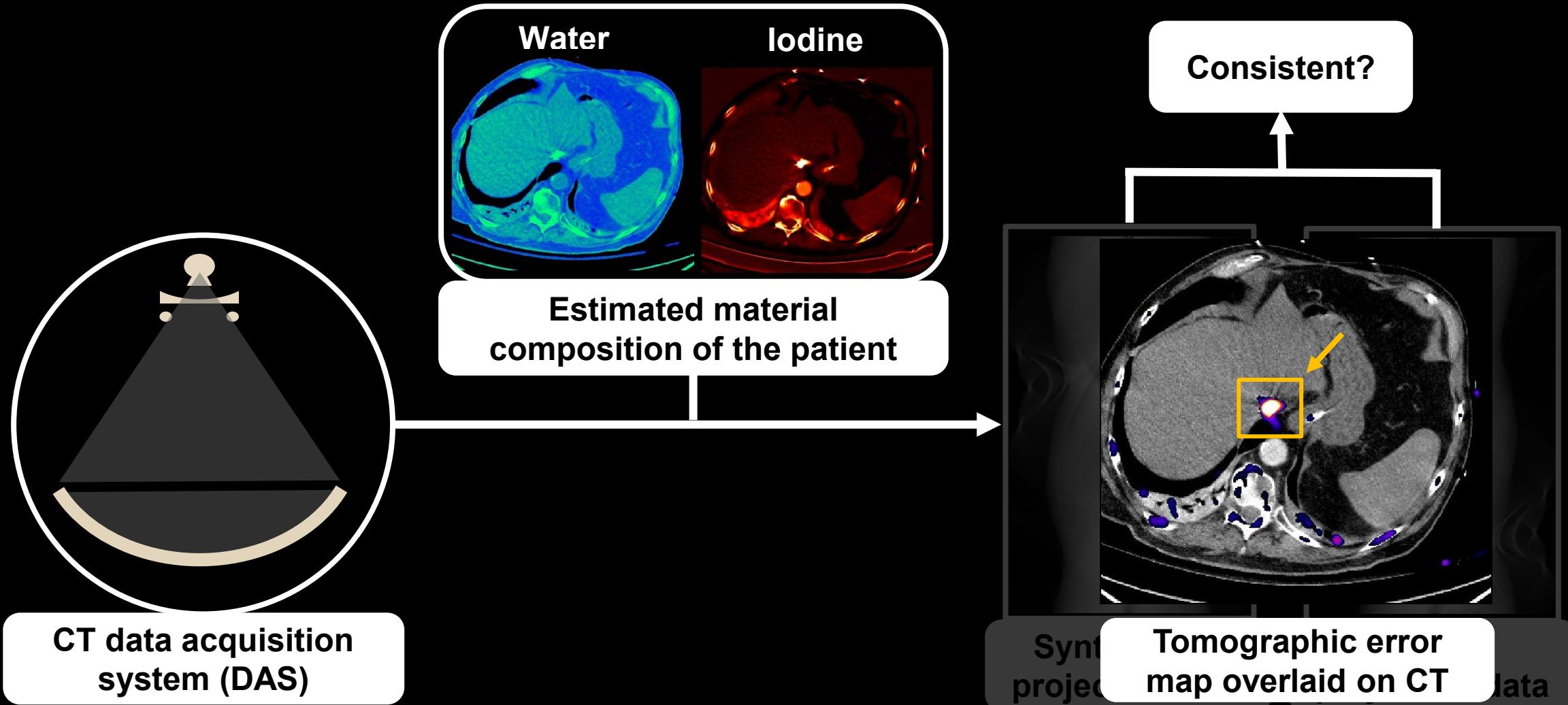


Purpose

- To develop a novel Deep-QA framework to enable automated and proactive QA of AI-based images for individual patients
 - Example: Deep-QA of AI-based material image estimation from single-kV CT



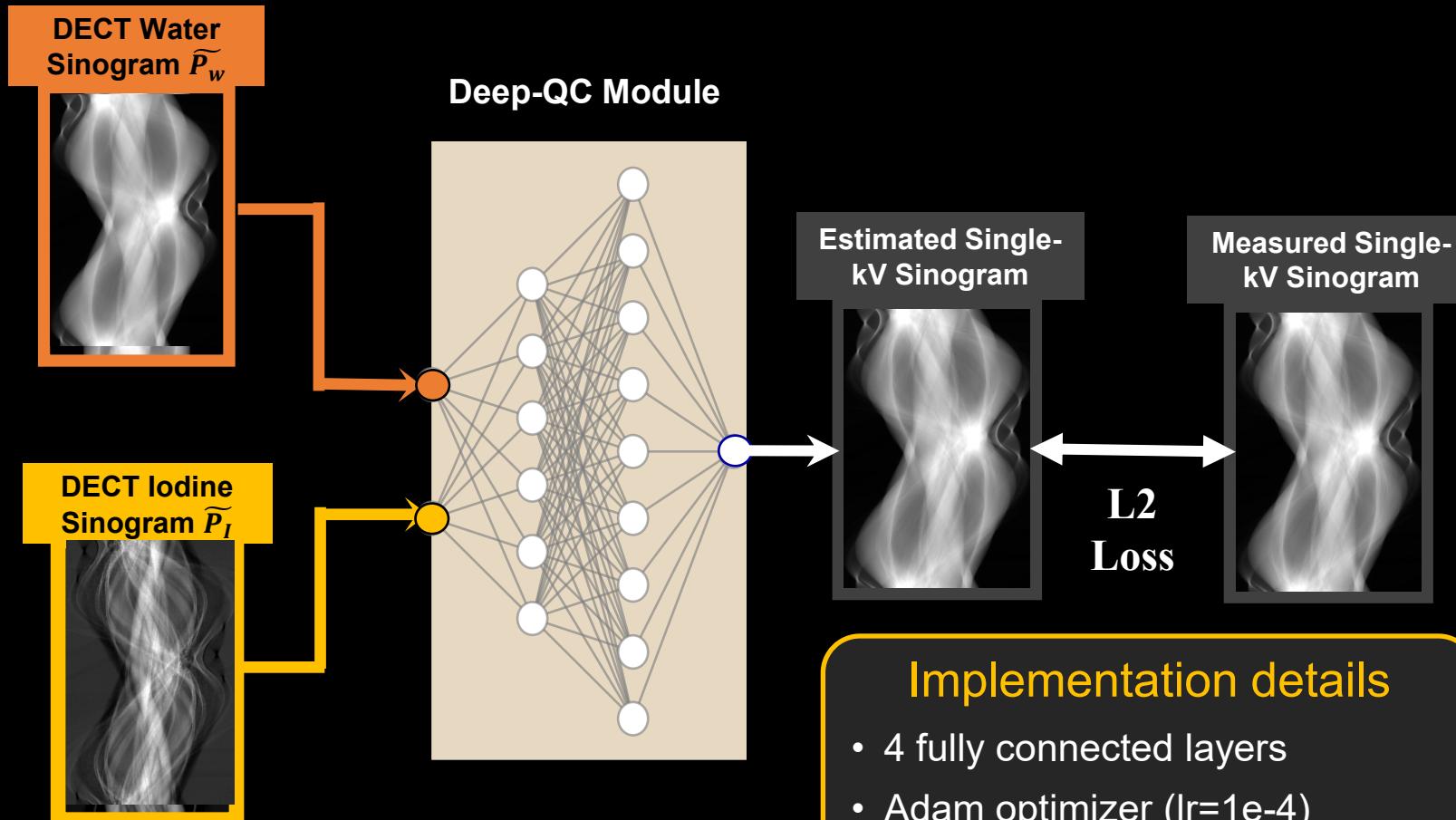
Basic Principle of the Deep-QA Framework





Architecture of the Deep-QA Framework

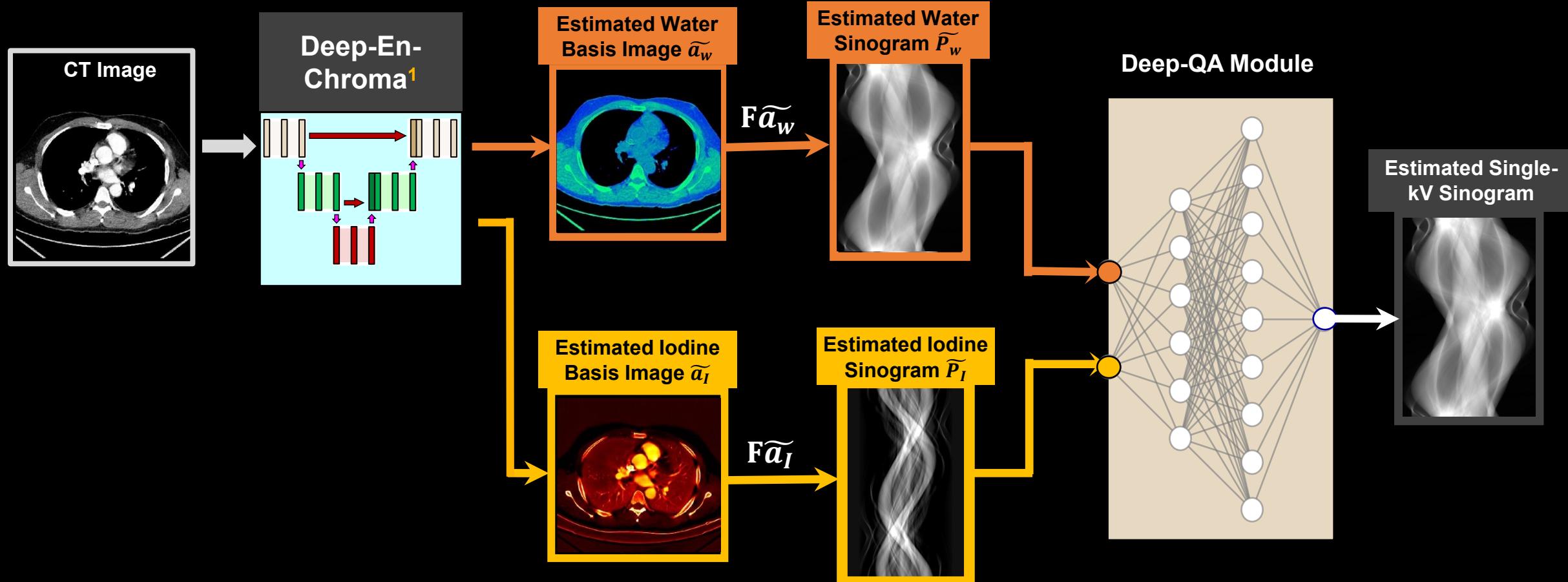
Training stage:





Architecture of the Deep-QA Framework

Inference stage:

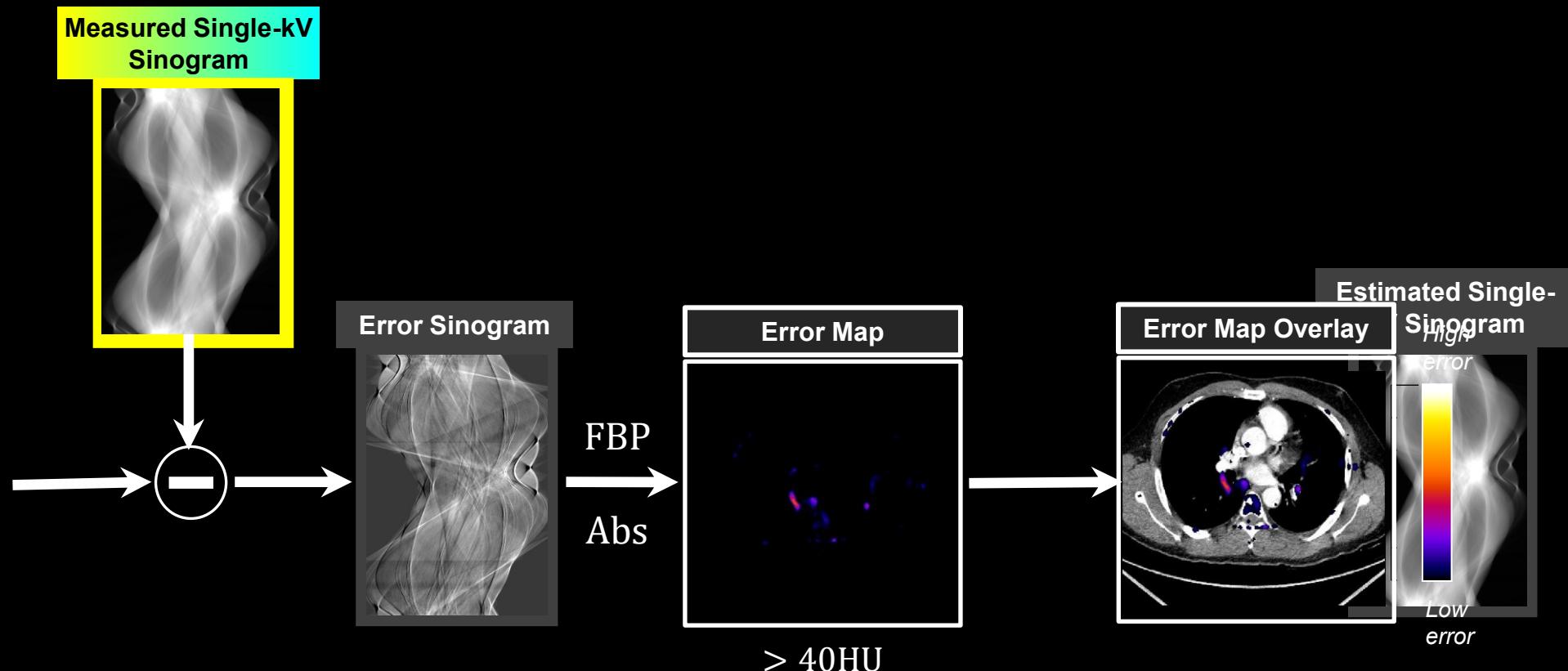


* \mathbf{F} denotes the forward projection



Architecture of the Deep-QA Framework

Inference stage:



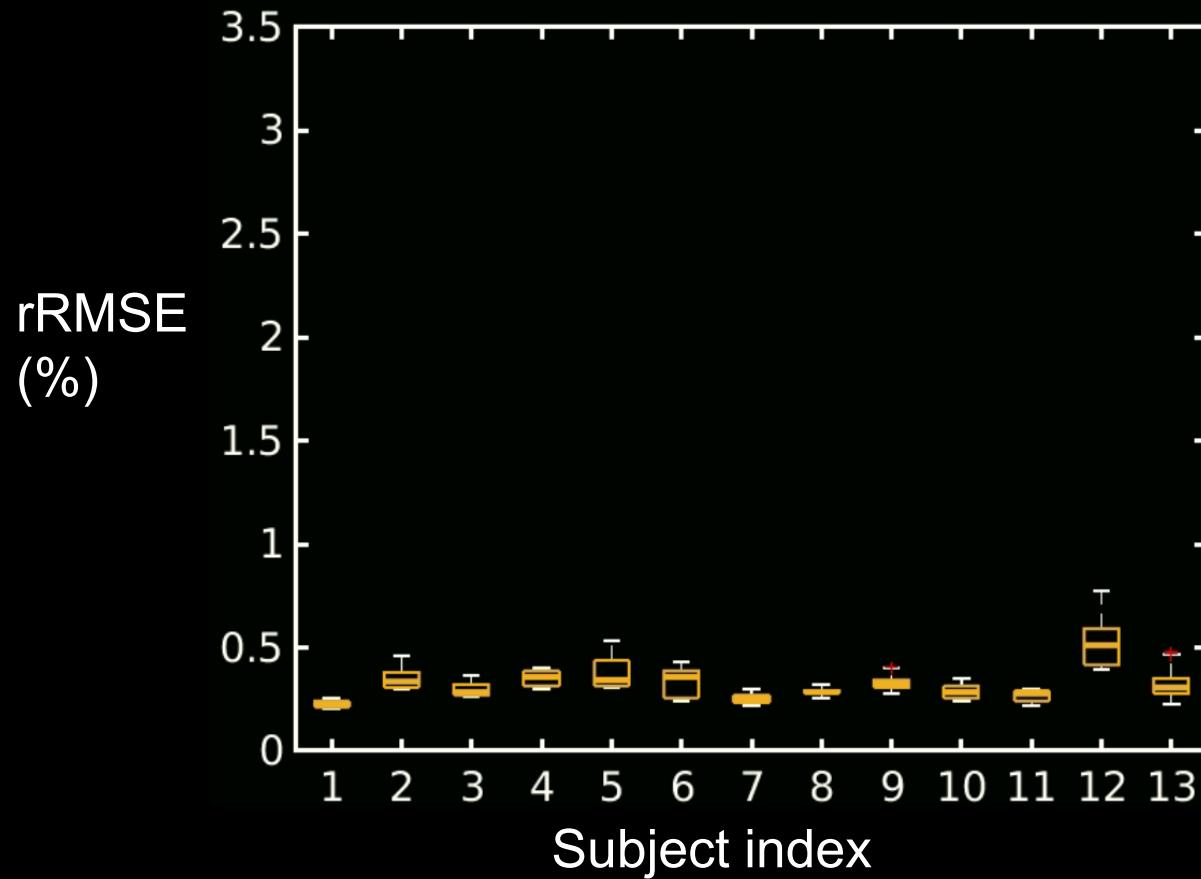
Training and Testing Datasets



- 45 sets of clinical dual-energy pulmonary CT angiography (CTA) sinogram and image data were retrospectively collected
 - 64-slice MDCT scanner (Discovery CT 750 HD) and fast-kV switching (Gemstone Spectral Imaging or GSI) mode
 - Sinogram data for each given scan were obtained using a proprietary software toolkit provided by the vendor
 - 29 were randomly selected for training (4034 slices), 3 were used for validation, and the remaining 13 subjects were used for testing

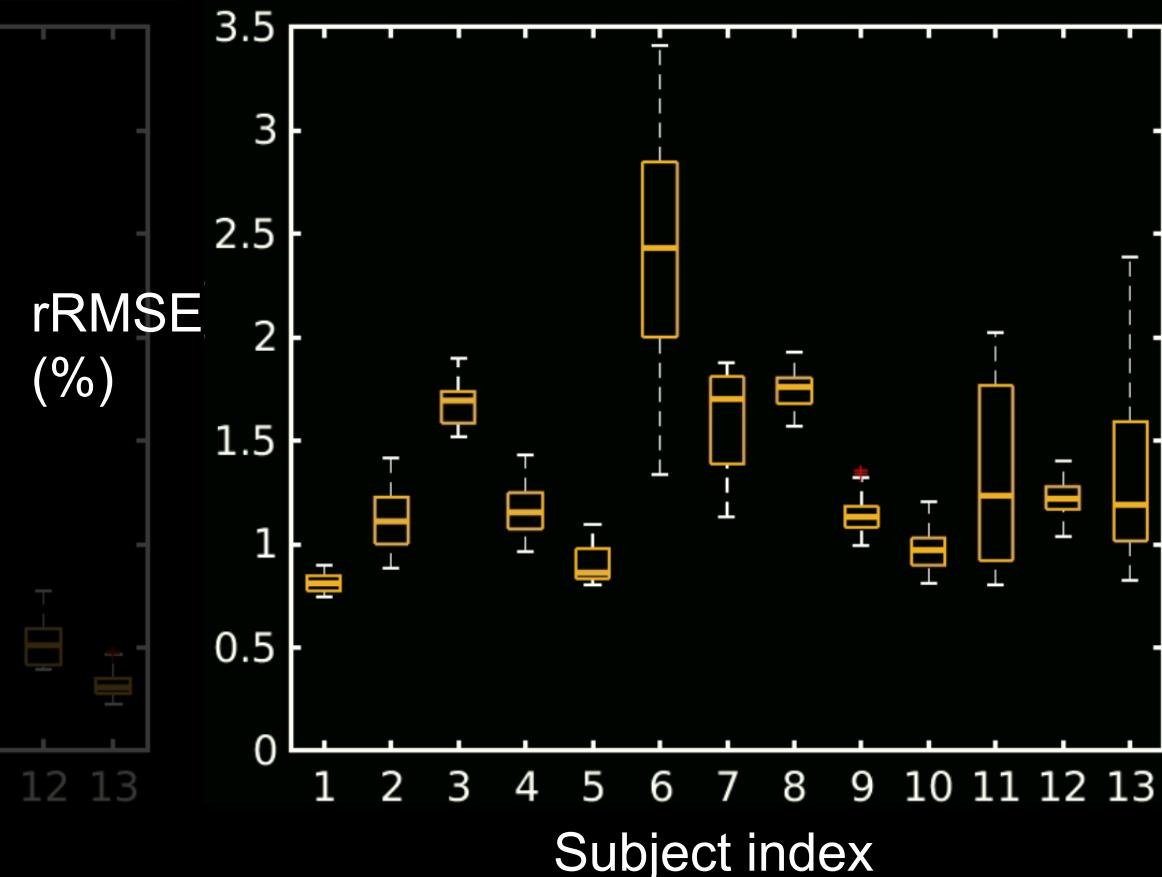
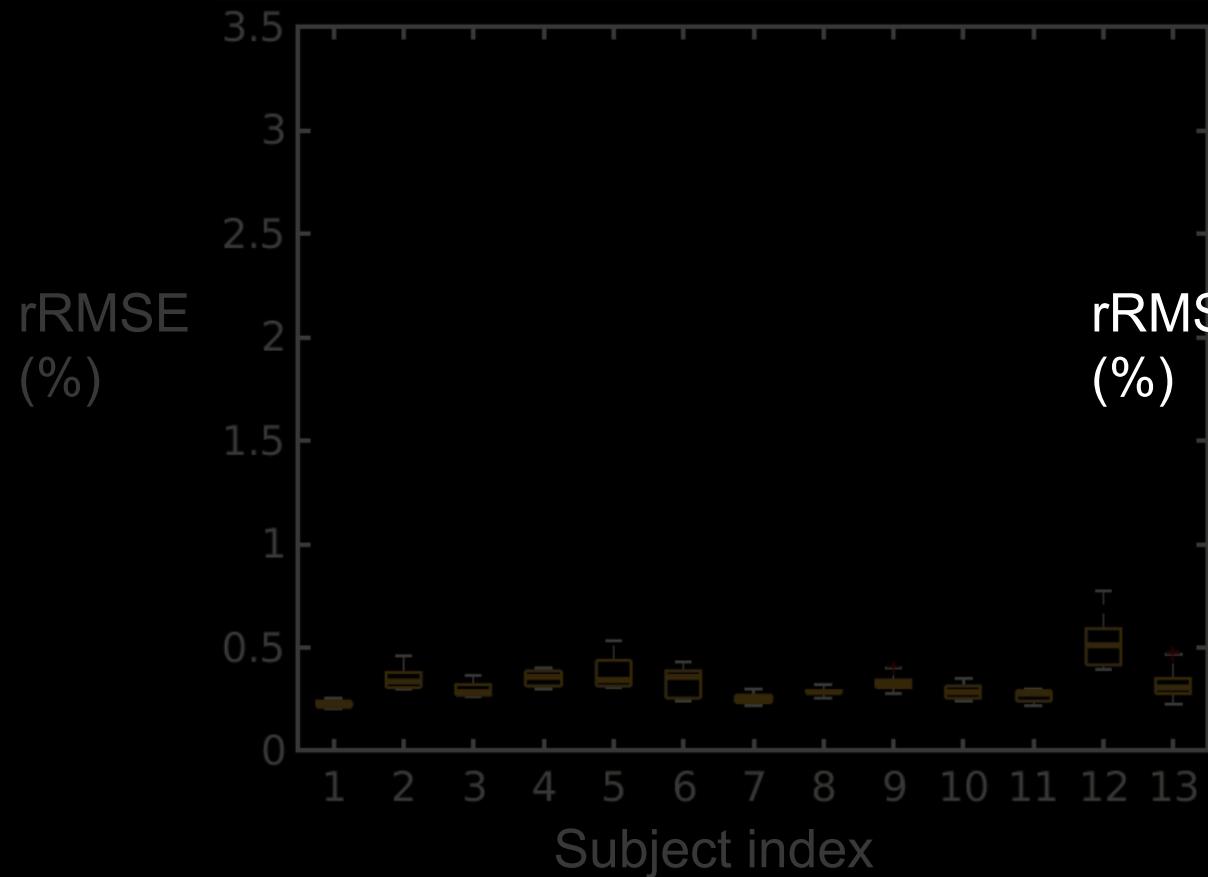
Quantitative Results

- When the inputs are ground true material basis images, the median rRMSE of the synthesized sinogram is 0.31% with [25th, 75th percentiles] of [0.27%, 0.36%]



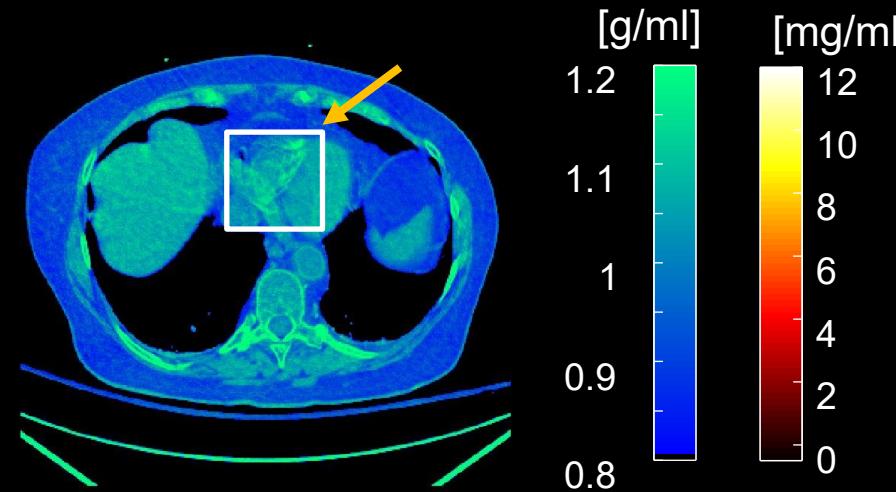
Quantitative Results

- When the inputs are changed to deep-learning material basis images (the same patient cohort), rRMSE of the output sinogram is 1.19% [1.00%, 1.65%]

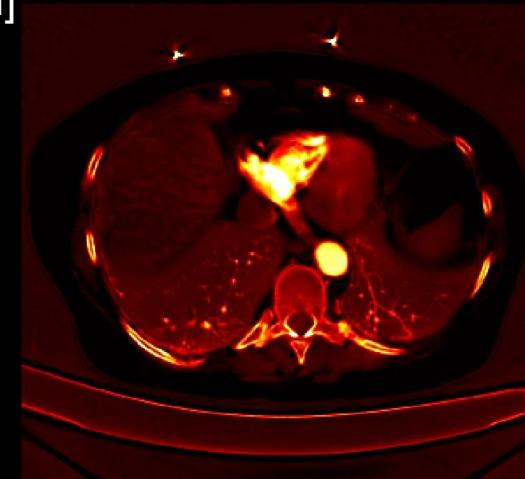
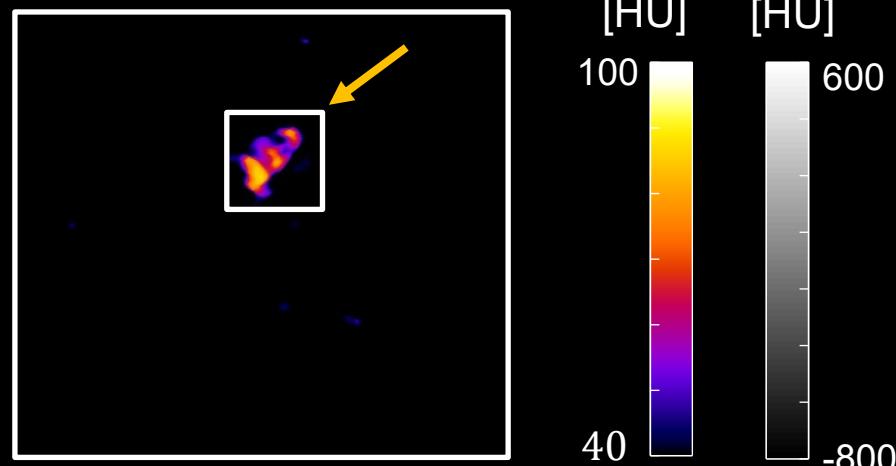


Error Maps: Human Subjects

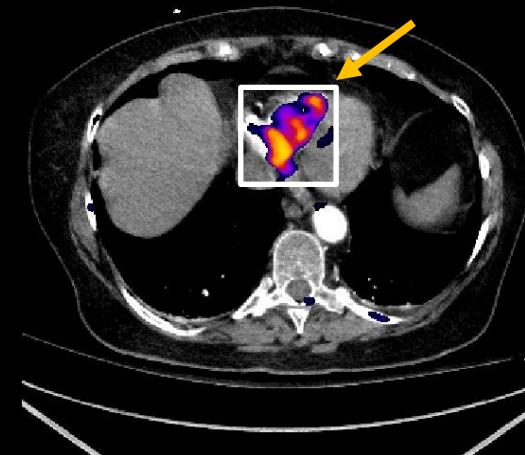
Deep-En-Chroma
water basis image



Deep-QA
error map



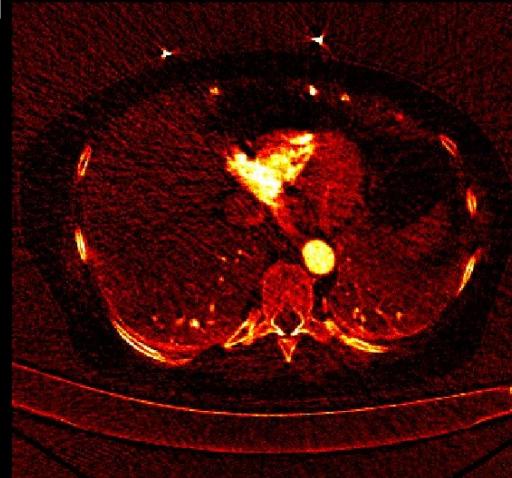
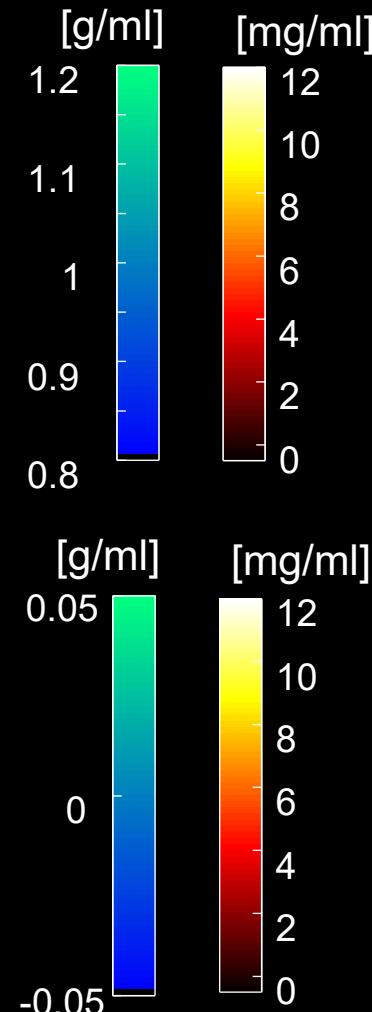
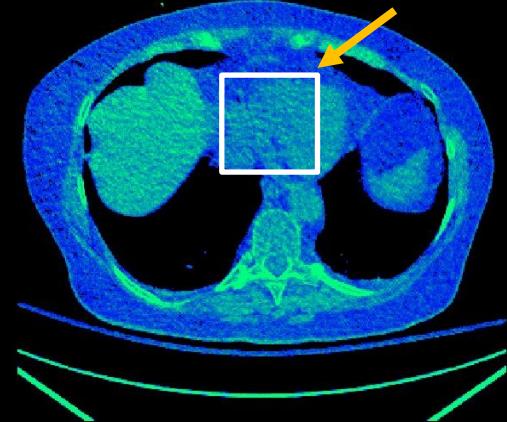
Deep-En-Chroma
iodine basis image



Error map-CT
image overlay

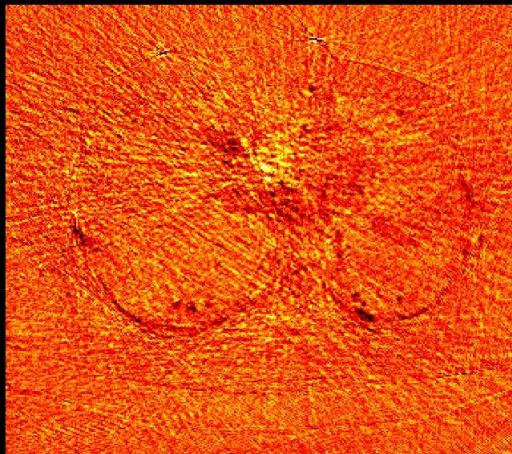
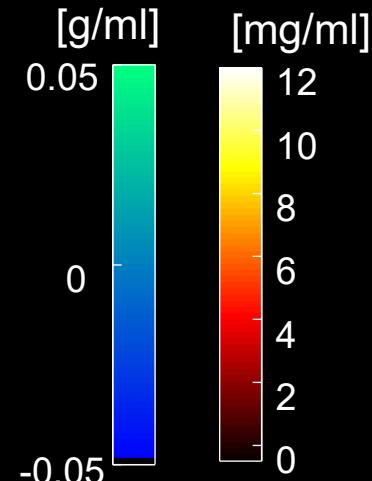
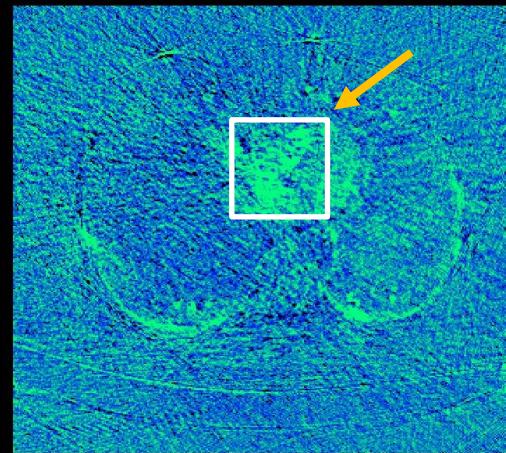
Error Maps: Human Subjects

DECT
water basis image



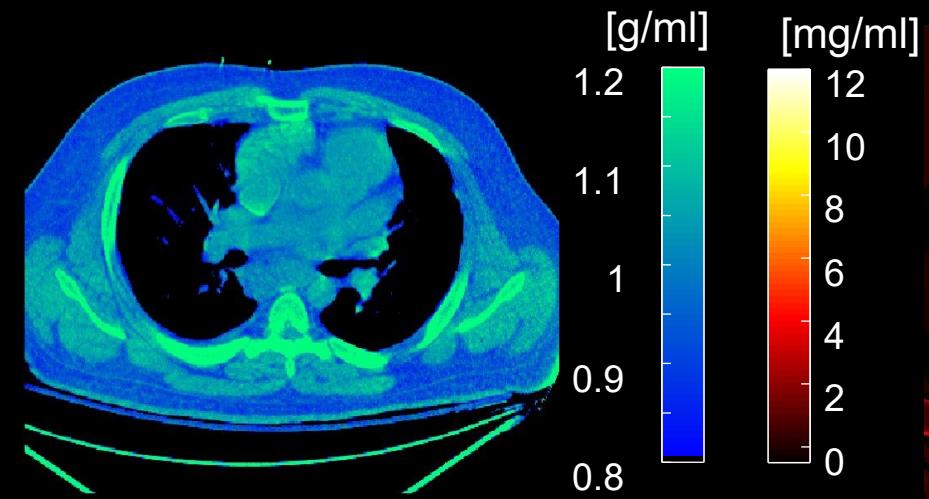
DECT
iodine basis image

Difference

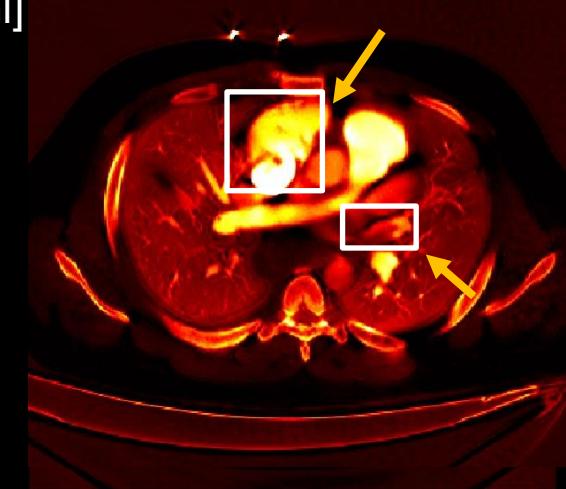


Error Maps: Human Subjects

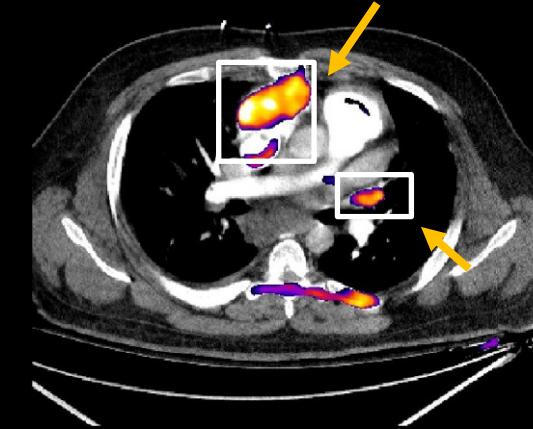
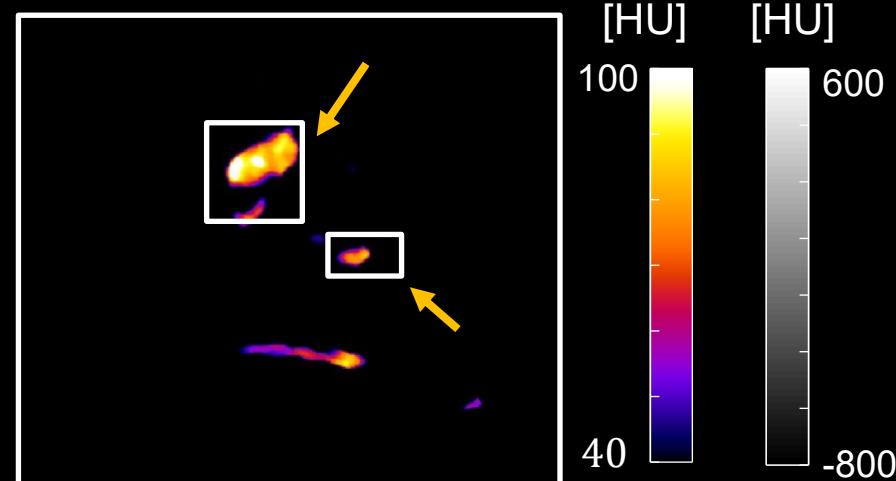
Deep-En-Chroma
water basis image



Deep-En-Chroma
iodine basis image



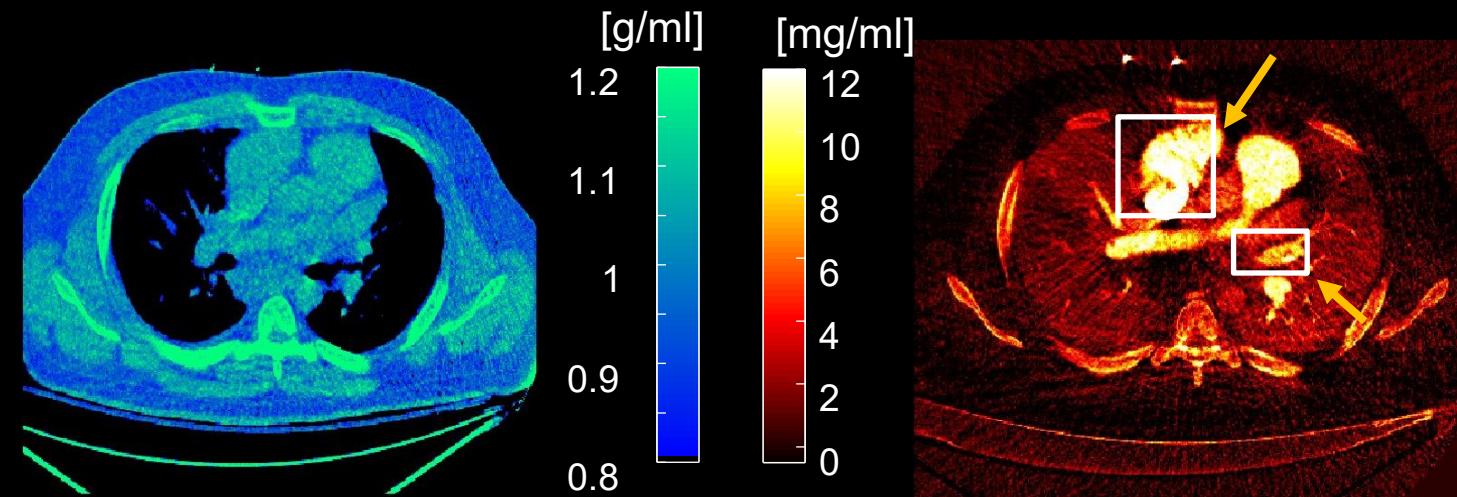
Deep-QC
error map



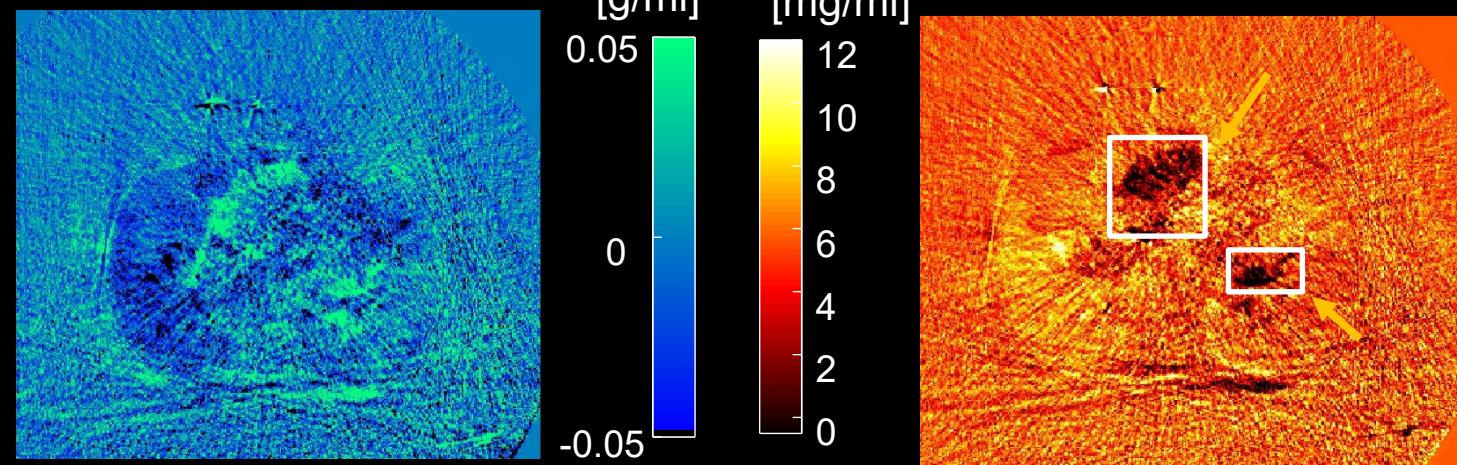
Error map-CT
image overlay

Error Maps: Human Subjects

DECT
water basis image



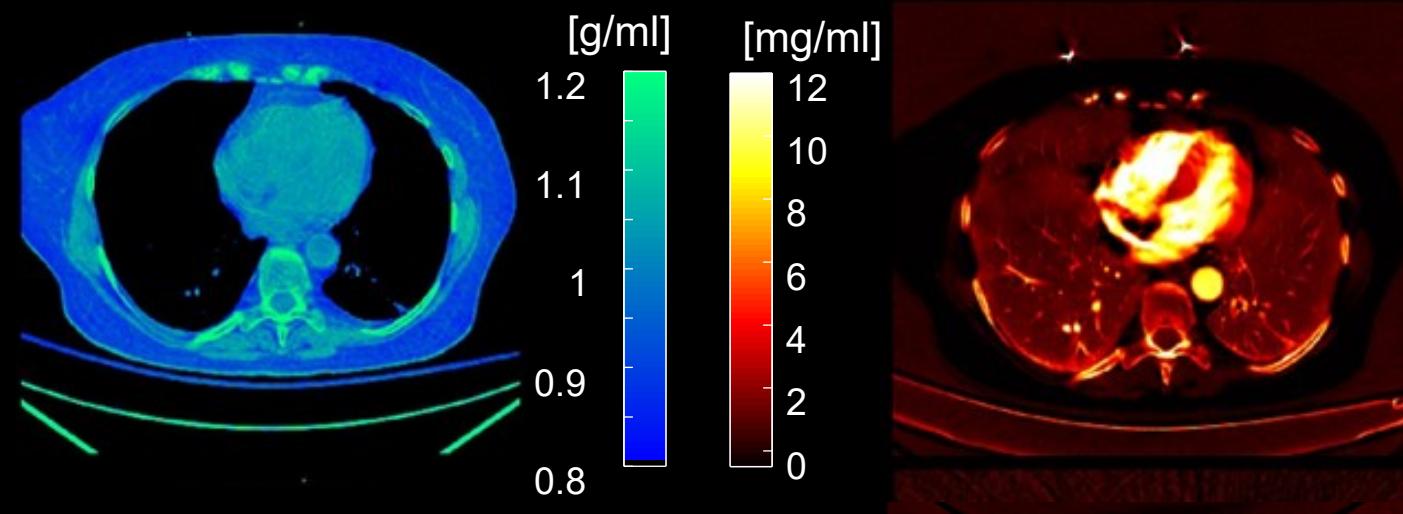
Difference



DECT
iodine basis image

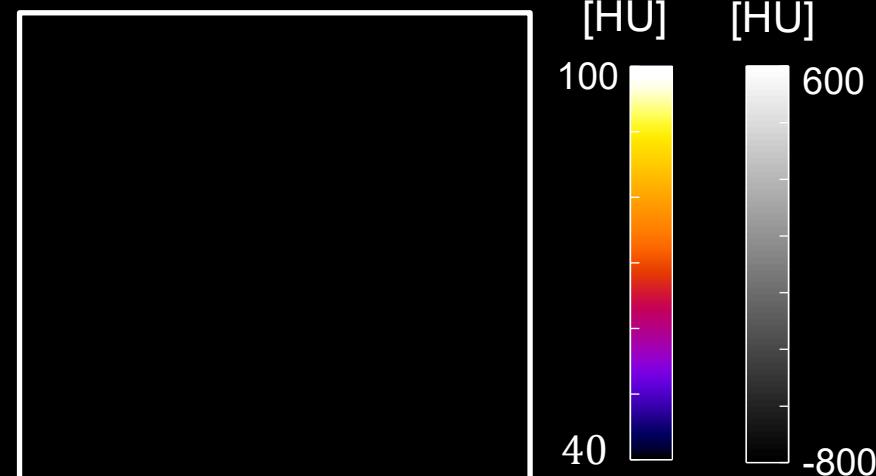
Error Maps: Human Subjects

Deep-En-Chroma
water basis image



Deep-En-Chroma
iodine basis image

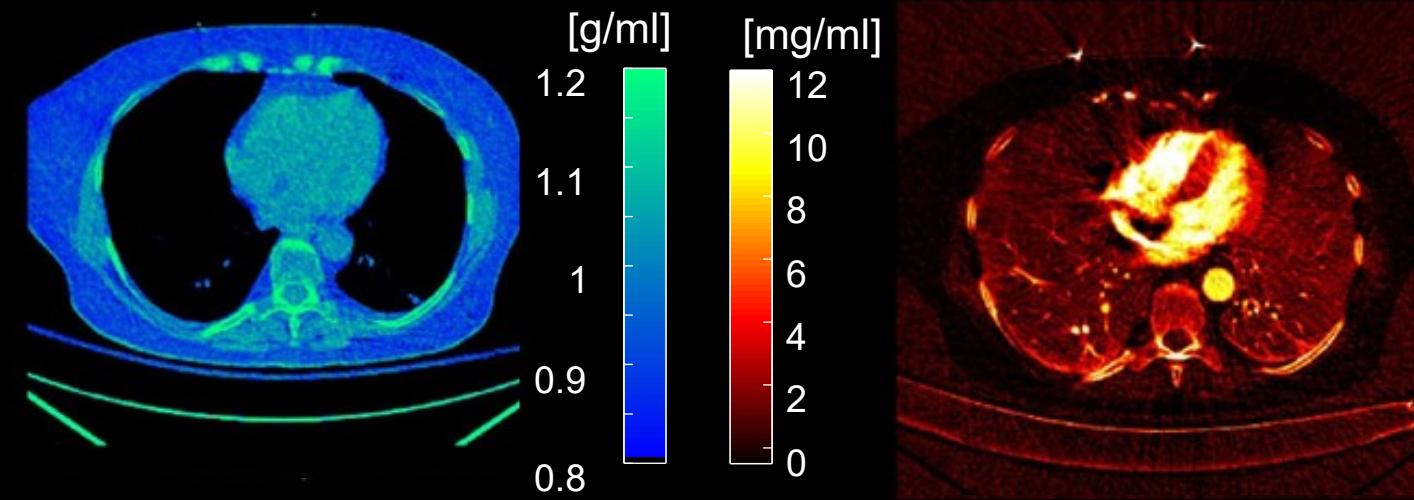
Deep-QC
error map



Error map-CT
image overlay

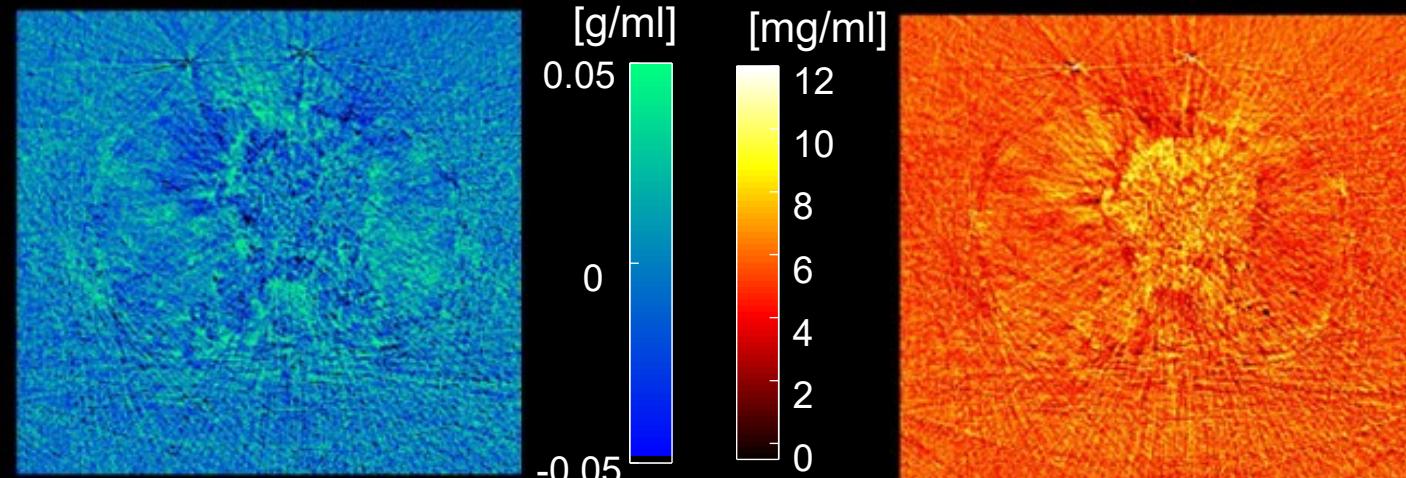
Error Maps: Human Subjects

DECT
water basis image



DECT
iodine basis image

Difference



$$\Delta\mu_0 = 40 \text{ HU}$$

Summary



- A new automated QA mechanism is introduced in this work to capture both locations and magnitude of estimation errors made by a DL method (i.e., Deep-En-Chroma) when processing medical images for individual patients
- It allows physicians to be informed about the reliability of AI-based material basis images
- Investigate how to incorporate error information from the Deep-QA maps to perform patient specific corrections



Thank You



University of Wisconsin-Madison