Improving delineation and response assessment using DECT in RT

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Disclosure

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Why dual-energy CT (DECT)?
By using two different energies, DECT allows material decomposition based on energy-dependent attenuation profiles of specific materials.

Comparing to conventional single-energy CT, DECT allows additional comprehensive post-processing to generate a variety of other images:
- Virtual mono-energetic decomposition image, enabling a desired energy of 40-190 keV to achieve better contrast.
- Virtual material-specific iodine images, enabling differentiation of hypodense tumors from hypo- or hyperdense cysts (e.g., pancreatic masses and peritoneal disease, better defining tumor targets).

Clinical DECT scanner introduced in 2005. Initially for diagnostic applications:
- Differentiation of urinary stones
- Imaging of pulmonary embolism
- Neuro imaging or differentiation of pulmonary nodules

Applications of DECT in RT:
- Improved dose calculation accuracy (brachytherapy, proton)
- Metal artifact reduction
- Tissue characterization
- Improved delineation
- Enhanced response assessment
- Eliminating non-contrast scan when a contrast scan is acquired during simulation
6 DECT @ FH/MCW Rad Onc

- **Siemens Drive**: dual source DECT
  - RT simulation
  - Summed dose equals a standard CT
  - Rapid acquisition minimizes motion effects
  - No motion between the two scans
- **Siemens Confidence**: single source dual spiral DECT
  - RT simulation
- **Siemens Definition AS**: single source dual spiral DECT
  - Two for RT simulation
  - One as CT-on-rails for daily IGRT and response assessment during RT delivery

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**TH-A8-BBB1-1**: G Noid, D Schott, T Schmidt, A Tai, XA Li. Optimal Energy of Virtual Monoenergetic Imaging From Dual-Energy CT for Target Delineation and Radiation Response Assessment

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**Reducing metal artifacts**

- Virtual Monoenergetic images can restore image quality
- Higher energies reduce beam hardening
Reducing metal artifacts

- Virtual Monoenergetic images can restore image quality
- Higher energies reduce beam hardening

Prostate cancer CT with 120 kVp and 190 keV MEI + IMAR

Reducing image artifacts

Large mantle field with arms down imaged with 120 kVp, 140 kVp, and 190 keV MEI

motion blurring reduction

- Simultaneous DECT reduces motion related blurring effects
- Reduces uncertainty in segmentation

Pancreatic cancer (tail) imaged with Sequential & Simultaneous DECT
motion blurring reduction

- Simultaneous DECT reduces motion related blurring effects
- Reduces uncertainty in segmentation

Pancreatic cancer (celiac) imaged with Sequential & Simultaneous DECT

Sequential DECT

Simultaneous DECT

120 kVp non-contrast

120 kVp w contrast

Virtual unenhanced from DECT

50 keV

Registration error between contrast and non-contrast CTs

No registration error, eliminating non-contrast scan

Improving target delineation for pre-operative RT of breast cancer

- Virtual Monoenergetic images enhance soft tissue contrast
- Subtracted images enhance further

Invasive ductal carcinoma
Improving target delineation for pre-operative RT of breast cancer

Image contrast enhancement: Liver

Improved target delineation: Thymic carcinoma
Pancreatic cancer

DECT with IV bolus
Post-processing to quantify the concentration of iodine
Mapping vasculature
Left tonsil SCC with nodal involvement

Mapping Vasculature
Adenocarcinoma of pancreatic tail
Tissue composition

- Fat maps quantify the adipose tissue present in a voxel via multi-material decomposition
- Designed to work with liver
- Show potential to improve target delineation in brain

Meningioma imaged with Fat map and 70 keV

Tissue Differentiation

DECT of a pancreatic cancer patient.

Difference in kurtosis between the tumor in violet and the pancreatic stroma in cyan increases as X-ray energy decreases.

DECT for response assessment
Pancreatic tumor during chemo-RT

Correlation with pathological response
20 patients

DECT for treatment response

A table summarizing the mean CTN change (HU) in the target and aorta along with the target location for each patient.

A. The change in the mean CTN between the first and last week of treatment for the 20 pancreas patients in the study as measured at 120 kVp and 30 kVp.

B. A table summarizing the mean CTN change (HU) in the target and aorta along with the target location for each patient.
Pancreas
DECT amplify treatment response signal

DECT for pancreas treatment response

MRI-based DECT-guided pre-operative RT
PI: Adam Currey
DECT for treatment response

a: 40 keV  b: 50 keV  c: 60 keV

d: 40 keV  e: 50 keV  f: 60 keV

-0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0

(a-c) first fraction
(d-f) last fraction
Arrow: tumor

Breast Treatment Response

Summary

The use of DECT improves RT planning
- Increase of soft-tissue contrast using virtual monoenergetic images
- Reduction of image artifacts
- Mapping of vasculature
- Quantification of tissue composition
- Minimization of motion blurring

The use of DECT should be the standard practice.
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