Improving delineation and response assessment using DECT in RT

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Disclosure

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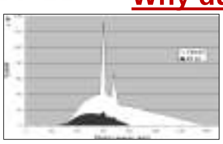
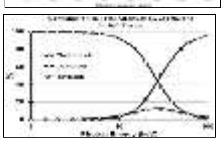
Siemens Healthineers
Elekta

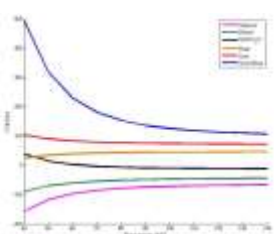
DECT: what, how and why

Why dual-energy CT (DECT)?

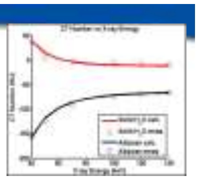




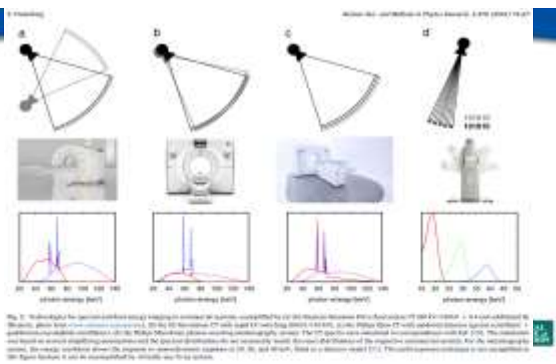
"Material differentiation by dual energy CT: initial experience" DOI: 10.1007/s00330-006-0517-6



Dual-Energy CT (DECT)

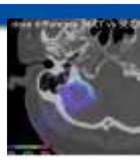


- By using two different energies, DECT allows material decomposition based on energy-dependent attenuation profiles of specific materials.
- Comparing to conventional single-energy CT, DECT allows additional comprehensive post-processing to generate a variety of other images:
  - Virtual mono-energetic decomposition image, enabling a desired energy of 40-190 keV to achieve better contrast)
  - Virtual material-specific iodine images, enabling differentiation of hypoattenuating tumors from hypo- or hyperattenuating 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

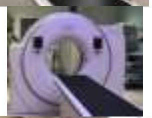
- Improved dose calculation accuracy (brachytherapy, proton)
- Metal artifact reduction
- Tissue characterization
- Improved delineation
- Enhanced response assessment
- Eliminating non-contrast scan when a contrast scan is acquired during simulation
- ………..



Hudobivnik MP 43:495

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 (2 systems)
  - RT simulation
- **Siemen Definition AS**: single source dual spiral DECT (3 systems)
  - Two for RT simulation
  - One as CT-on rails for daily IGRT and response assessment during RT delivery



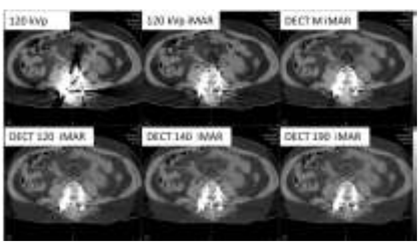
Technical Note: Enhancing soft tissue contrast and radiation induced image changes with dual-energy CT for radiation therapy.
Noid G, Tai A, Schott D, Mistry N, Liu Y, Schmidt TG, Robbins J, **Li XA**
Med Phys. 2018 Jul 4. doi: 10.1002/mp.13083. [Epub ahead of print]

AAPM 2018

SU-E-KDBRB1-4: G Noid, A Tai , D Schott , D Prah, N Mistry, J Robbins, XA Li. Advantages of Dual-Source Dual-Energy CT for Radiation Therapy Planning

TH-AB-DBRB-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

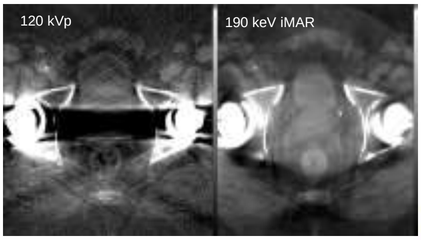
Reducing metal artifacts



CT of 120 kVp and MEI of DECT with and without iMAR

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

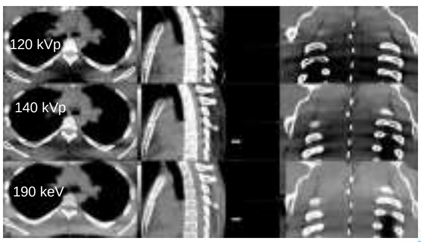
Reducing metal artifacts



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

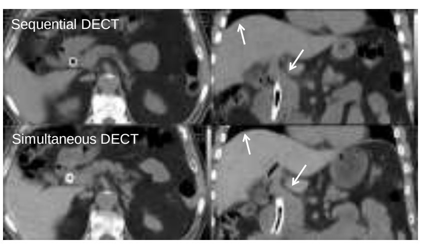
- Virtual Monoenergetic images can restore image quality
- Higher energies reduce beam hardening

Reducing image artifacts



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

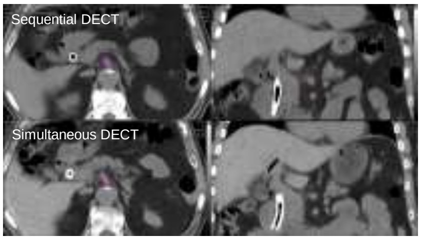
motion blurring reduction



Pancreatic cancer (celiac) imaged with Sequential & Simultaneous DECT

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

motion blurring reduction



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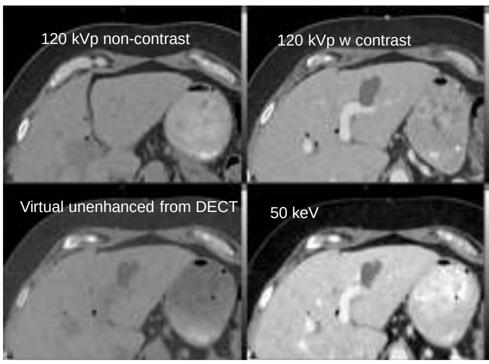
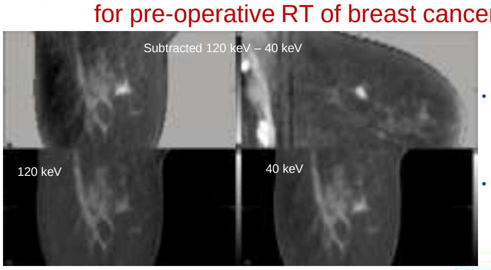


Registration error between contrast and non-contrast CTs

No registration error, eliminating non-contrast scan

Improving target delineation for pre-operative RT of breast cancer



Invasive ductal carcinoma

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

Improving target delineation for pre-operative RT of breast cancer

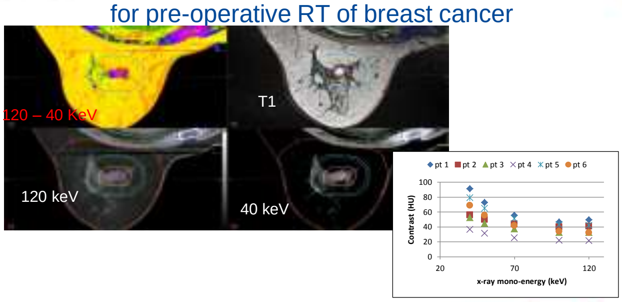
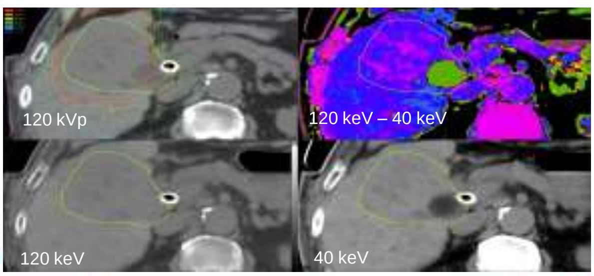
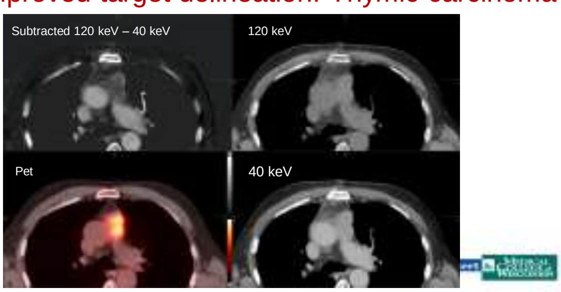


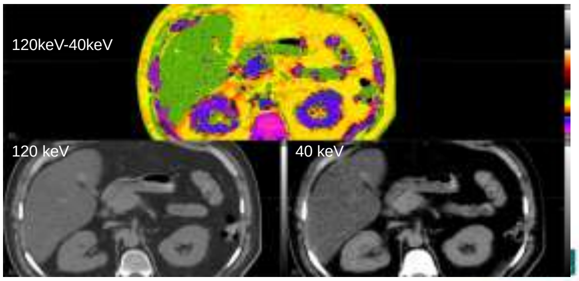
Image contrast enhancement: Liver

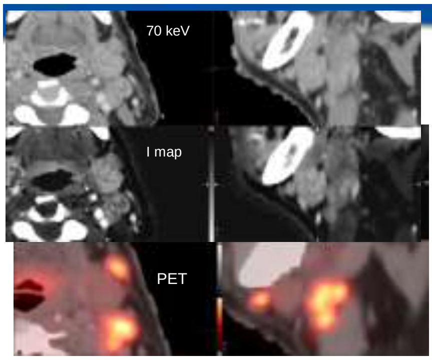


Improved target delineation: Thymic carcinoma



Pancreatic cancer





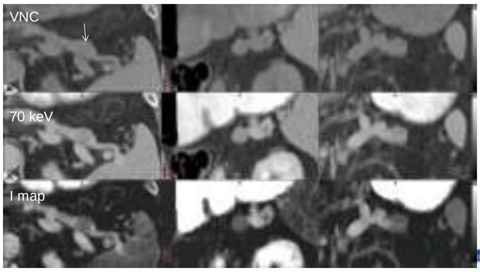
DECT with IV bolus

Post-processing to quantify the concentration of Iodine

Mapping vasculature

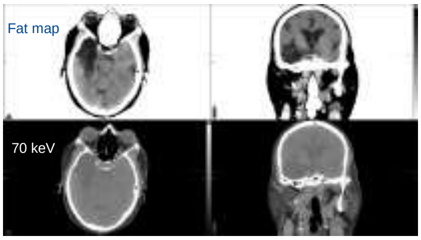
Left tonsil SCC with nodal involvement

Mapping Vasculature



Adenocarcinoma of pancreatic tail

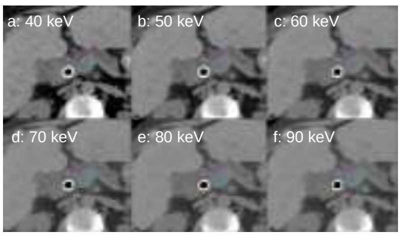
Tissue composition

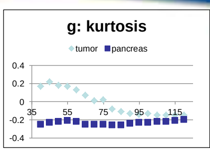


Meningioma imaged with Fat map and 70 keV

- 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

Tissue Differentiation



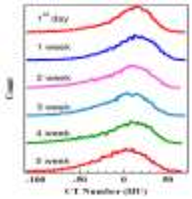


DECT of a pancreatic cancer patient.

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

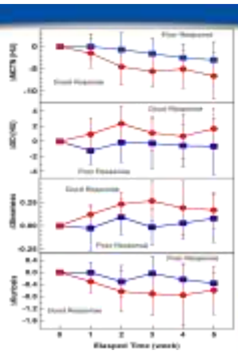


1st Fraction   26th Fraction

Assessment of treatment response during chemoradiation therapy for pancreatic cancer based on quantitative radiomic analysis of daily CTs: An exploratory study.
Chen X, Oshima K, Schott D, Wu H, Hall W, Song Y, Tao Y, Li D, Zheng C, Knechtges P, Erickson B, Li XA.
PLoS One. 2017 Jun 2;12(6):e0178961. doi: 10.1371/journal.pone.0178961. eCollection 2017.

Correlation with pathological response

20 patients

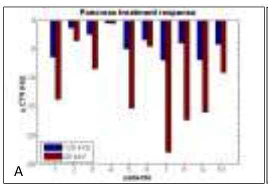


P=0.046

P=0.058

P=0.042

DECT for treatment response



Pt#	Target (HU) Δ40	Target (HU) Δ120	Aorta (HU) Δ40	Aorta (HU) Δ120	Target location
1	-13.74	-6.39	-1.72	-1.11	pancreatic head
2	-3.56	-1.33	-0.95	-0.4	pancreatic head
3	-8.44	-2.4	-0.4	-0.87	pancreatic neck & body
4	-0.55	-0.5	0.05	1.3	pancreatic head
5	-15.29	-4.95	-1.03	-0.1	ampulla vater & pancretic invasion
6	-4.5	-3.44	-1.27	-3.48	pancreatic head
7	-22.92	-6.89	-2.29	2.33	pancreatic head
8	-17.36	-3.96	-0.95	-0.3	pancreatic head
9	-15.97	-6.88	-1.27	-1.14	pancreatic head
10	-9.12	-4.14	-0.64	-0.04	pancreatic head

B

A The change in the mean CTN between the first and last week of treatment for the 10 pancreas patients in the study as measured at 120 kVp and 40 keV. **B**. A table summarizing the mean CTN change (HU) in the target and aorta along with the target location for each patient

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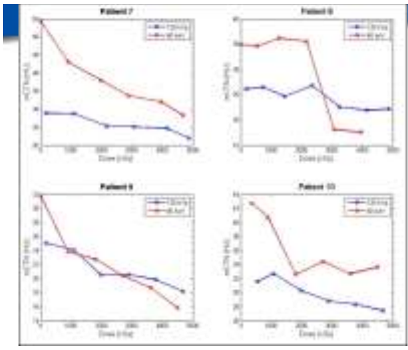
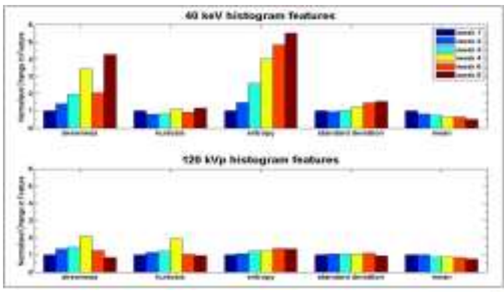


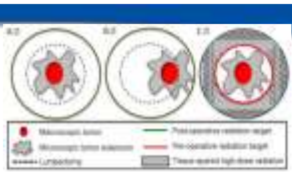
Pancreas

DECT amplify treatment response signal

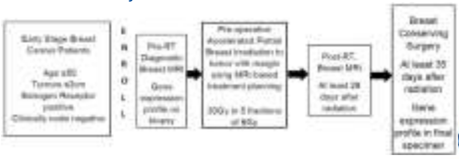
DECT for pancreas treatment response



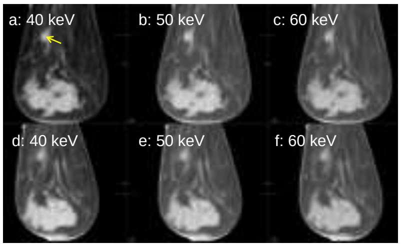
MRI-based DECT-guided pre-operative RT

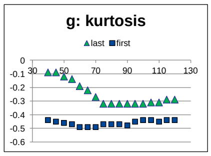


PI: Adam Currey



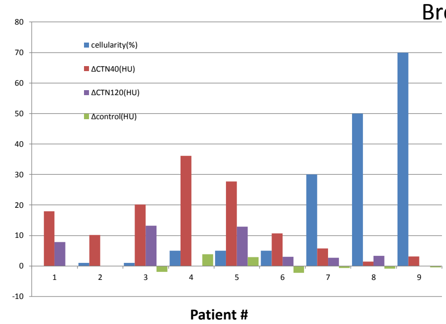
DECT for treatment response





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

Breast Treatment Response



Summary

The use of DECT improves RT planning

- Increase of soft-tissue contract 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.

Acknowledgements

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