2020 JULY 12–16 VIRTUAL EASTERN TIME [GMT-4]
JOINT AAPM | COMP MEETING
Improving Health QUALITY. Increasing Global IMPACT.

Applications of DECT: Tissue differentiation, Treatment response, and function assessment

Jessica Miller

July 15th, 2020

School of Medicine and Public Health
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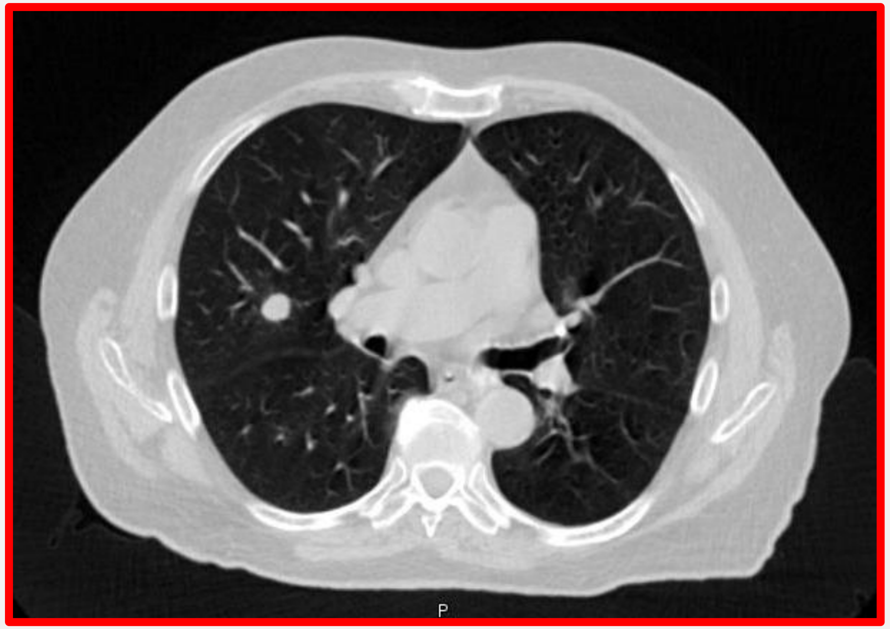
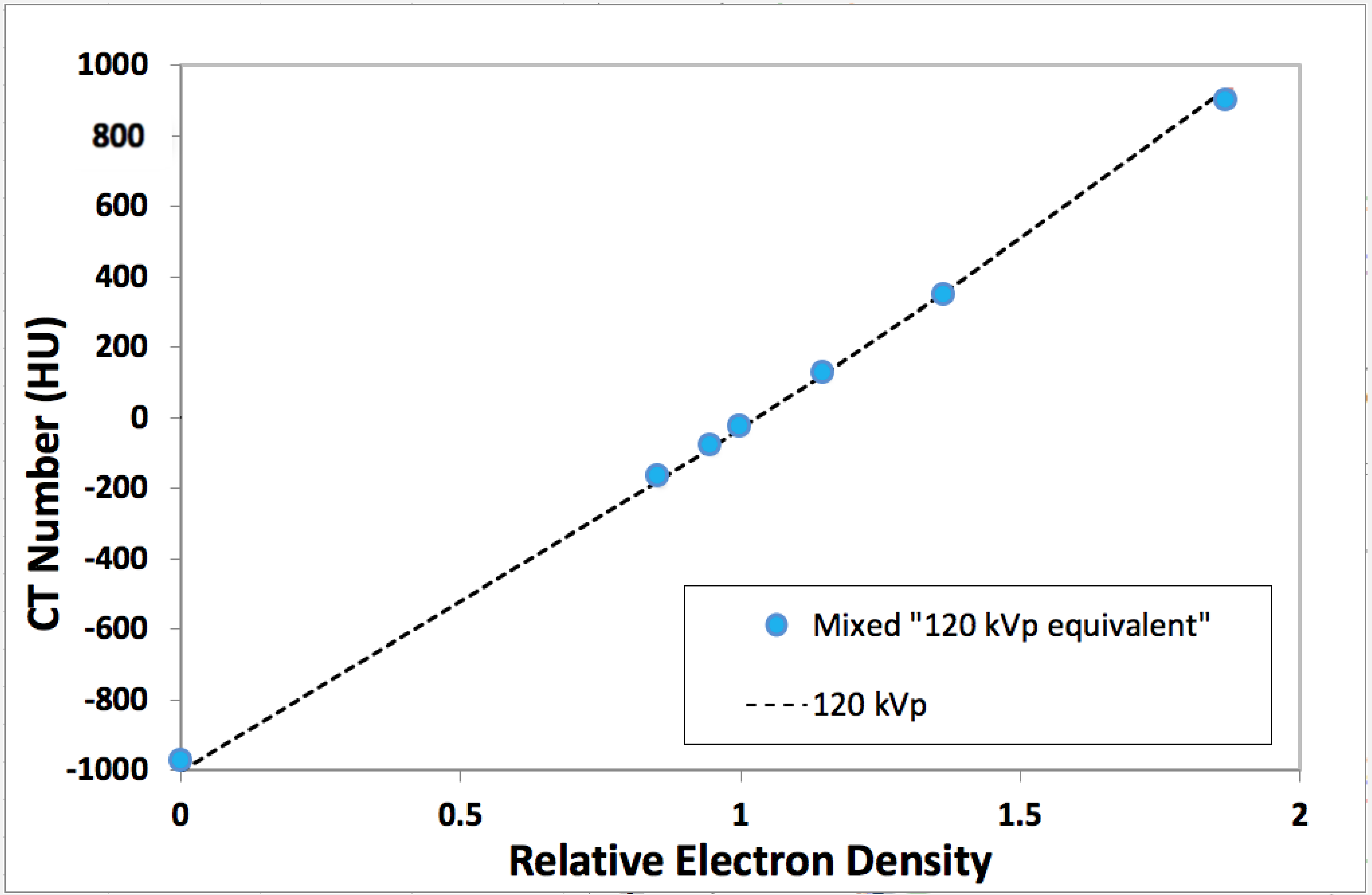
Learning objectives

- Discuss dual-energy CT derived images
- Highlight several application of DECT images within the radiation therapy space
    - Tumor and healthy tissue segmentation
    - Tumor characterization
    - Treatment response assessment using DECT
    - Functional tissue segmentation

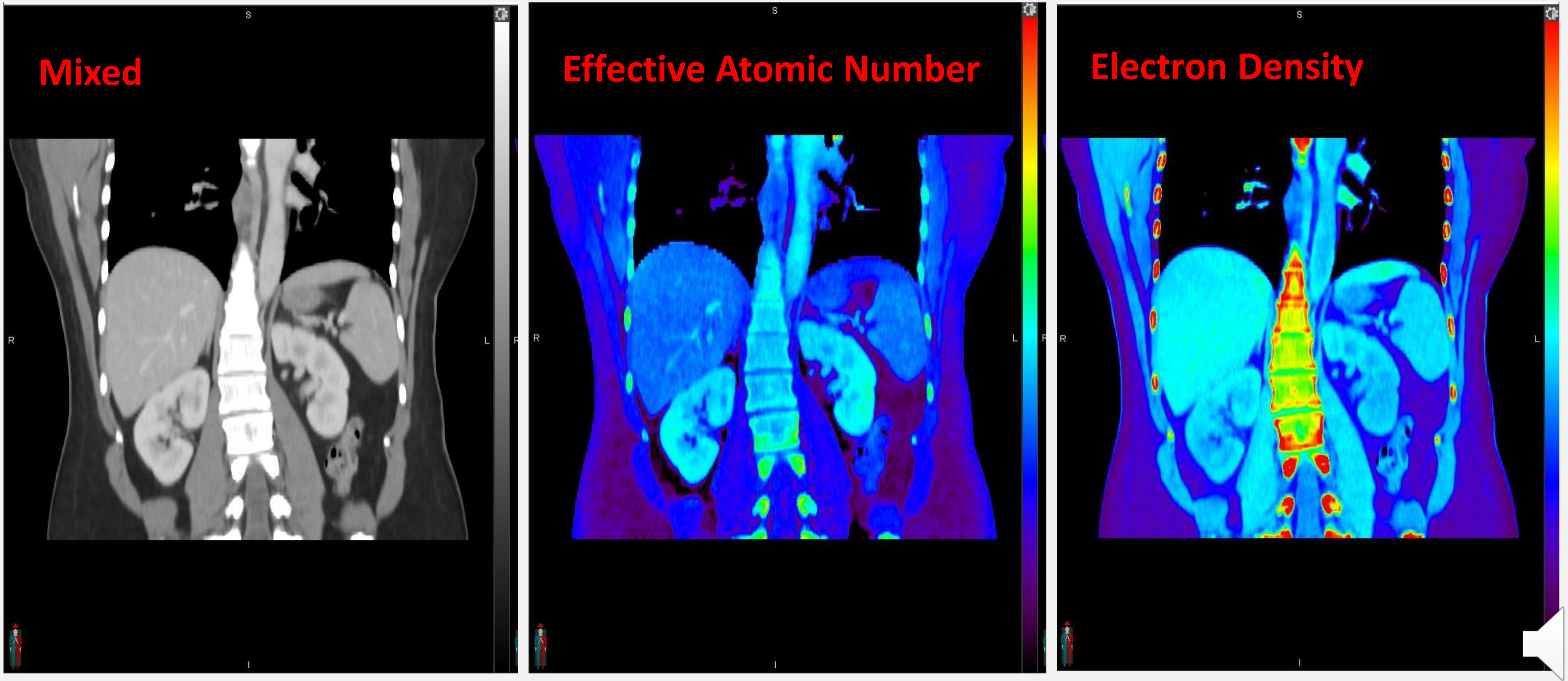
DECT in radiation therapy

Mixed – 120 kVp equivalent image





Effective atomic number and electron density images



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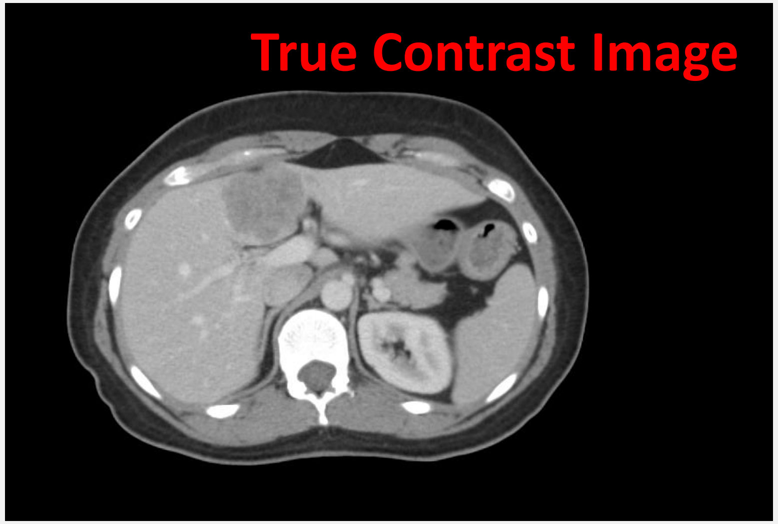
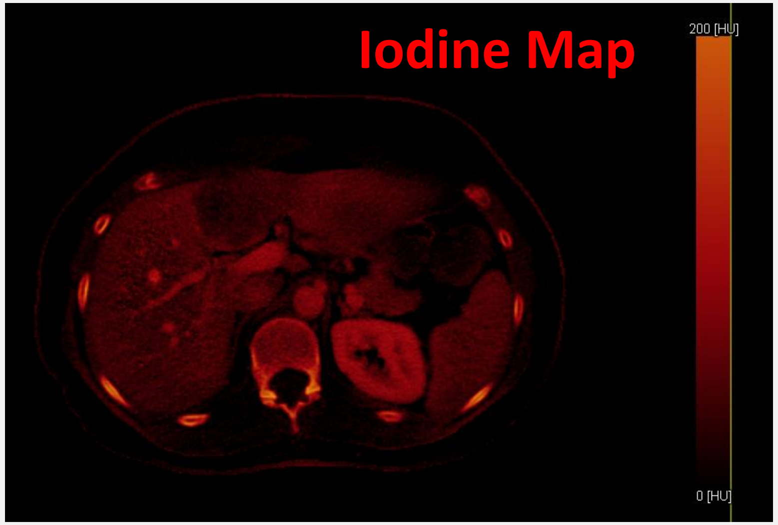
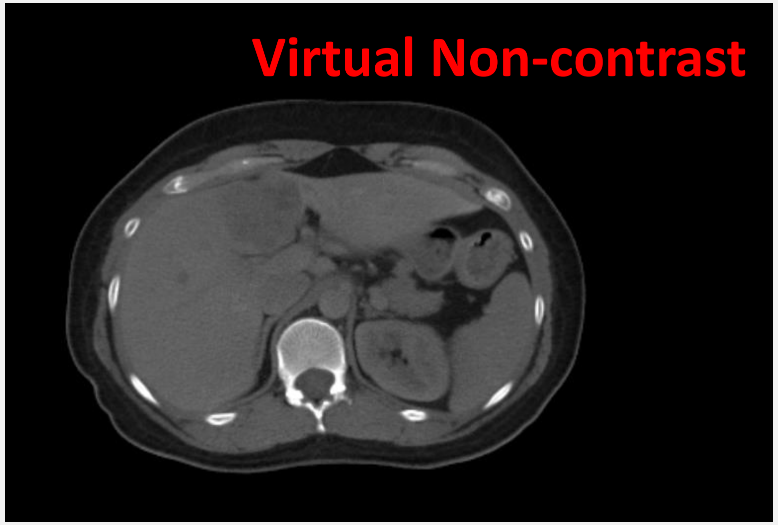
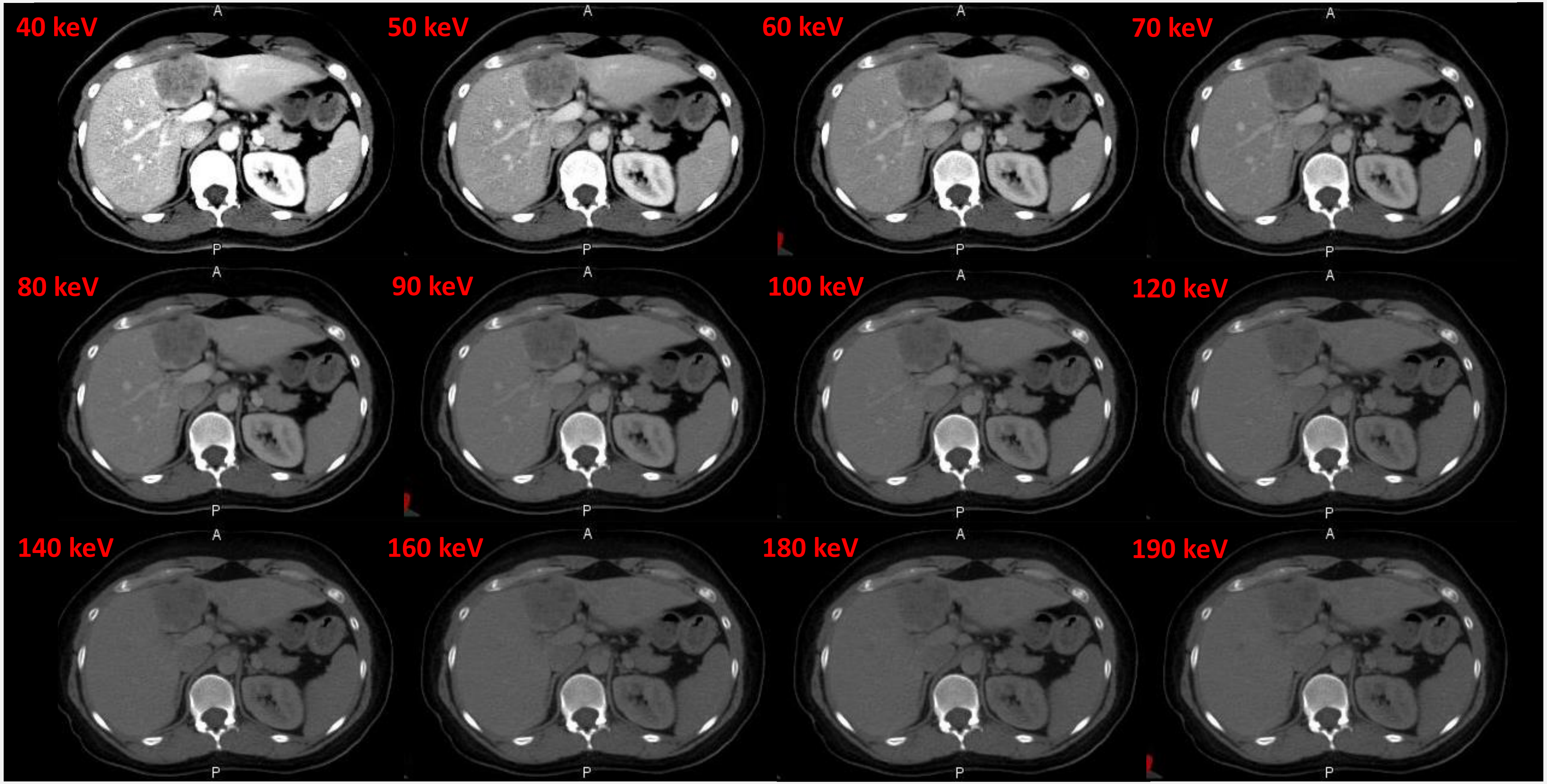
Material decomposition







Virtual Monoenergetic Images (VMI)



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Radiation therapy applications:

Tumor identification, characterization and delineation

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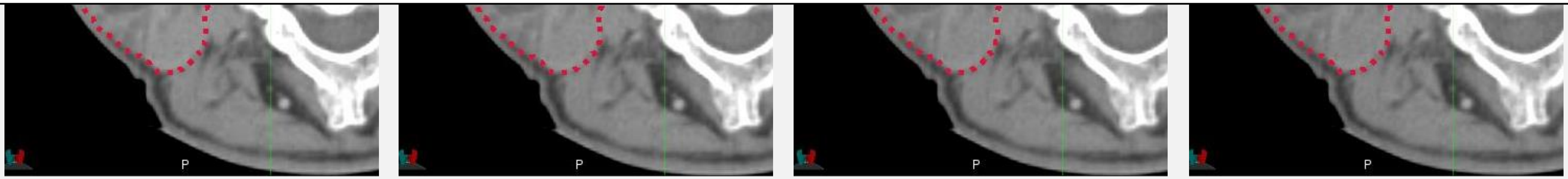
Tumor delineation for head and neck cancer

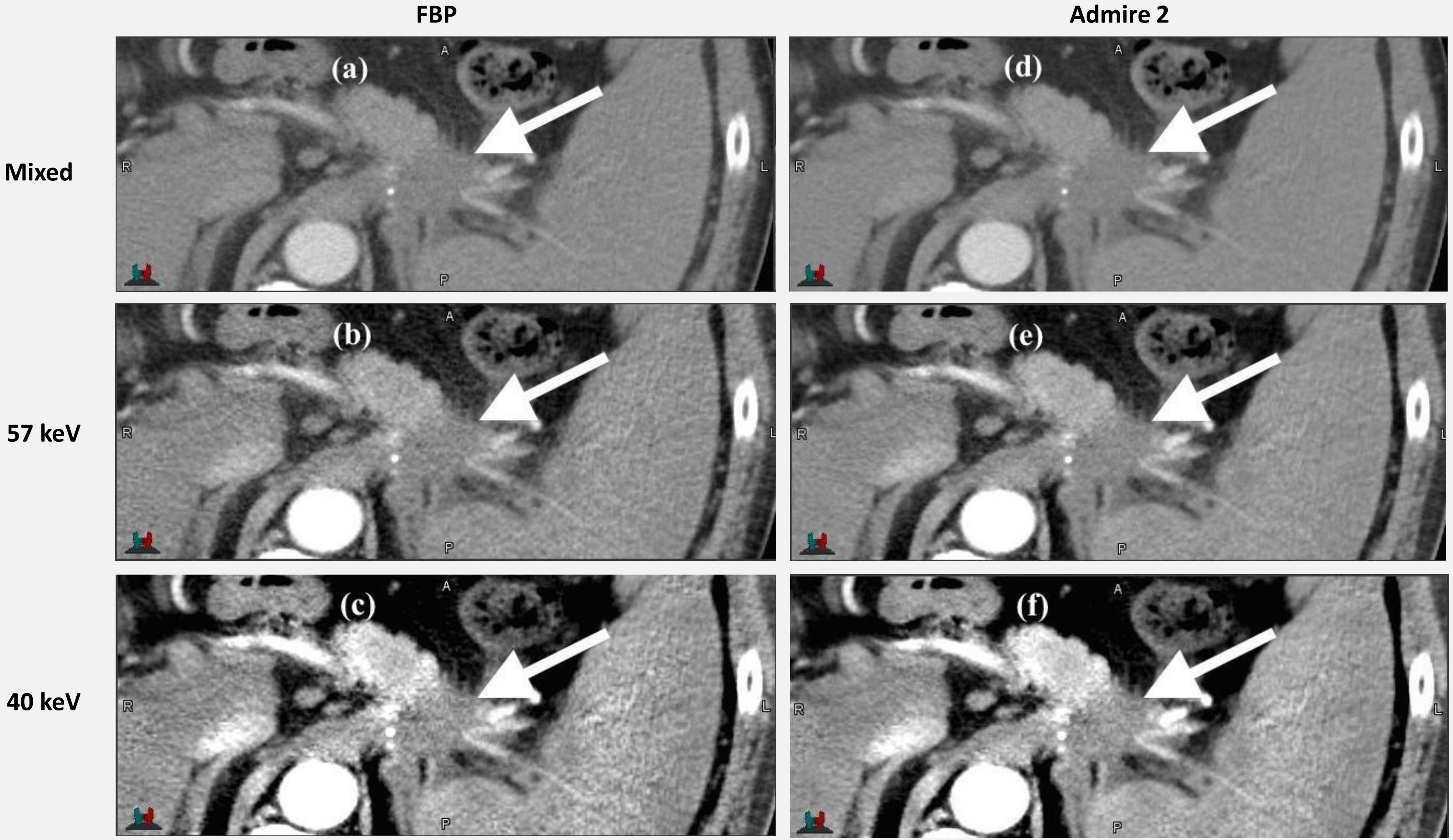
ORIGINAL ARTICLE (*Invest Radiol* 2014;49: 735–741)

Low-Energy Virtual Monochromatic Dual-Energy Computed Tomography Images for the Evaluation of Head and Neck Squamous Cell Carcinoma: A Study of Tumor Visibility Compared With Single-Energy Computed Tomography and User Acceptance

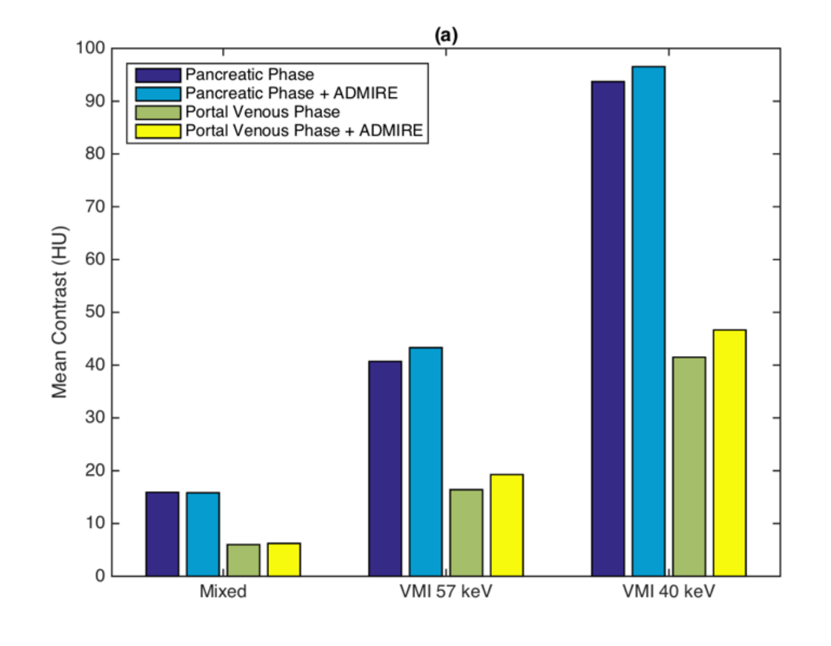
Reza Forghani, MD, PhD,†‡ Hillary Kelly, MD,§|| Eugene Yu, MD,¶ Manon Belair, MD,# Laurent Létourneau-Guillon, MD,# Huy Le, MD,* Francesca Proulx, MD,* Thomas Ong, MD, DMD,* Xianming Tan, PhD,** Hugh D. Curtin, MD,|| and Mark Levental, MD**



Tumor delineation for pancreatic cancer



Quantifying CNR gains in DECT pancreatic images



Lianna Di Maso et al. Journal of Applied Clinical Medical Physics (2018) 19(5): 676–683.

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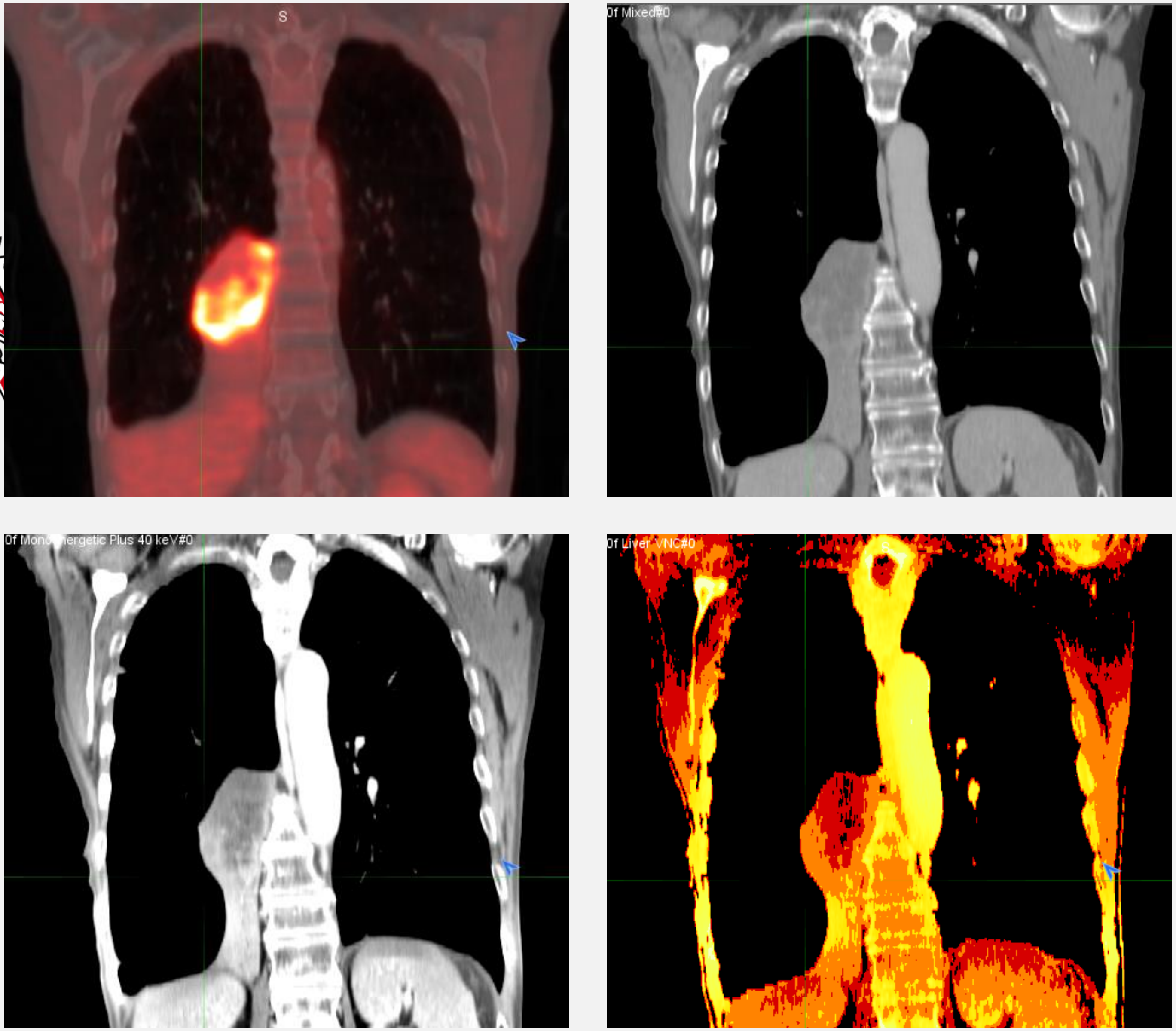
Tumor delineation for lung cancer



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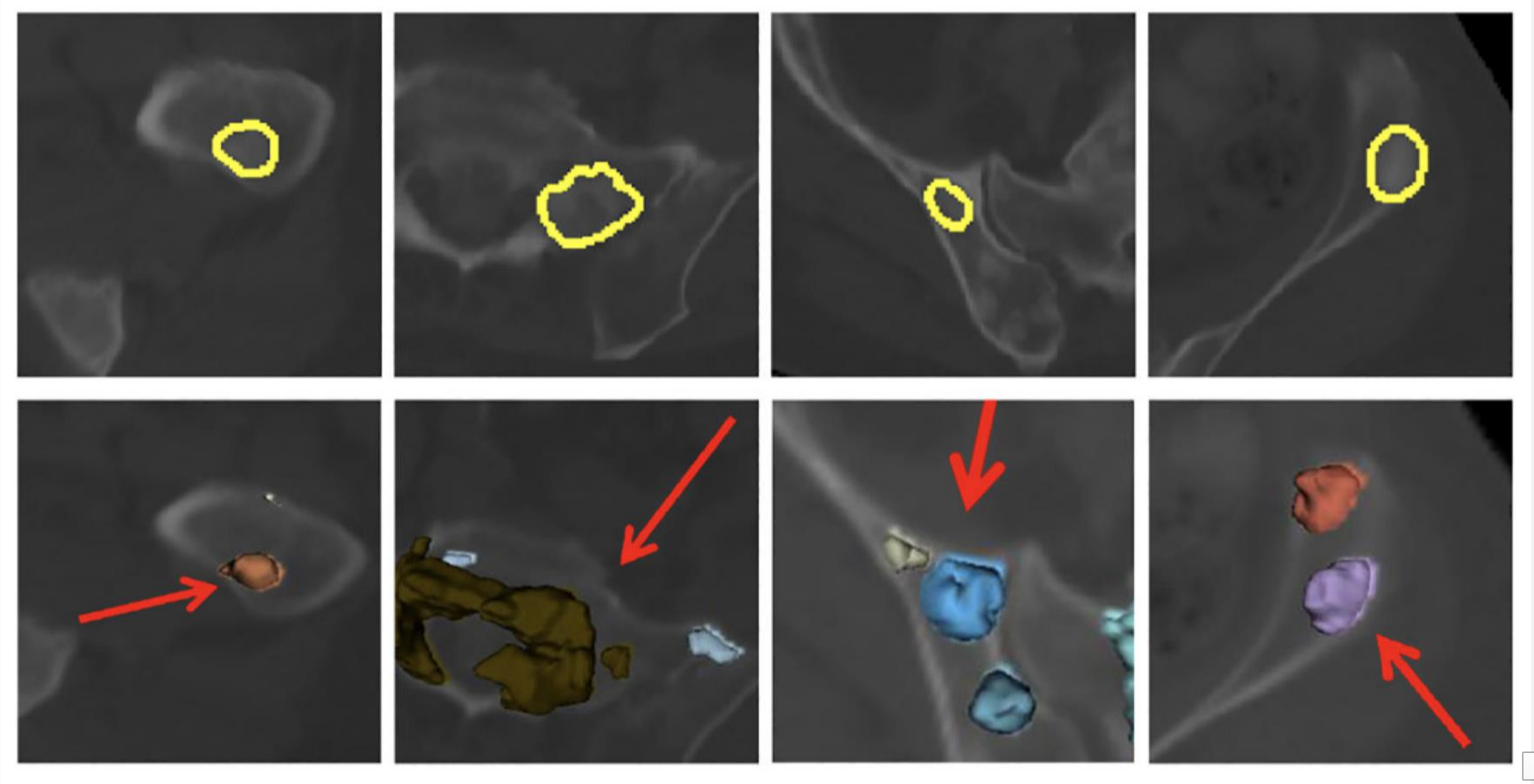
Bone lesion delineation



Duc Fehr et al. Proc IEEE Int Symp Biomed Imaging (2016) 168–171 .

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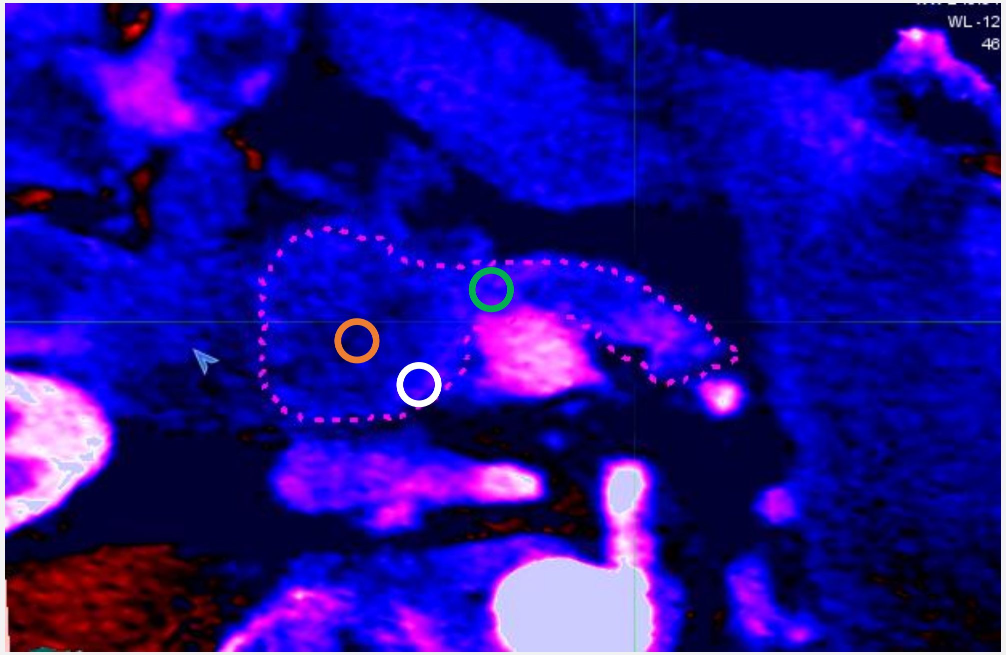
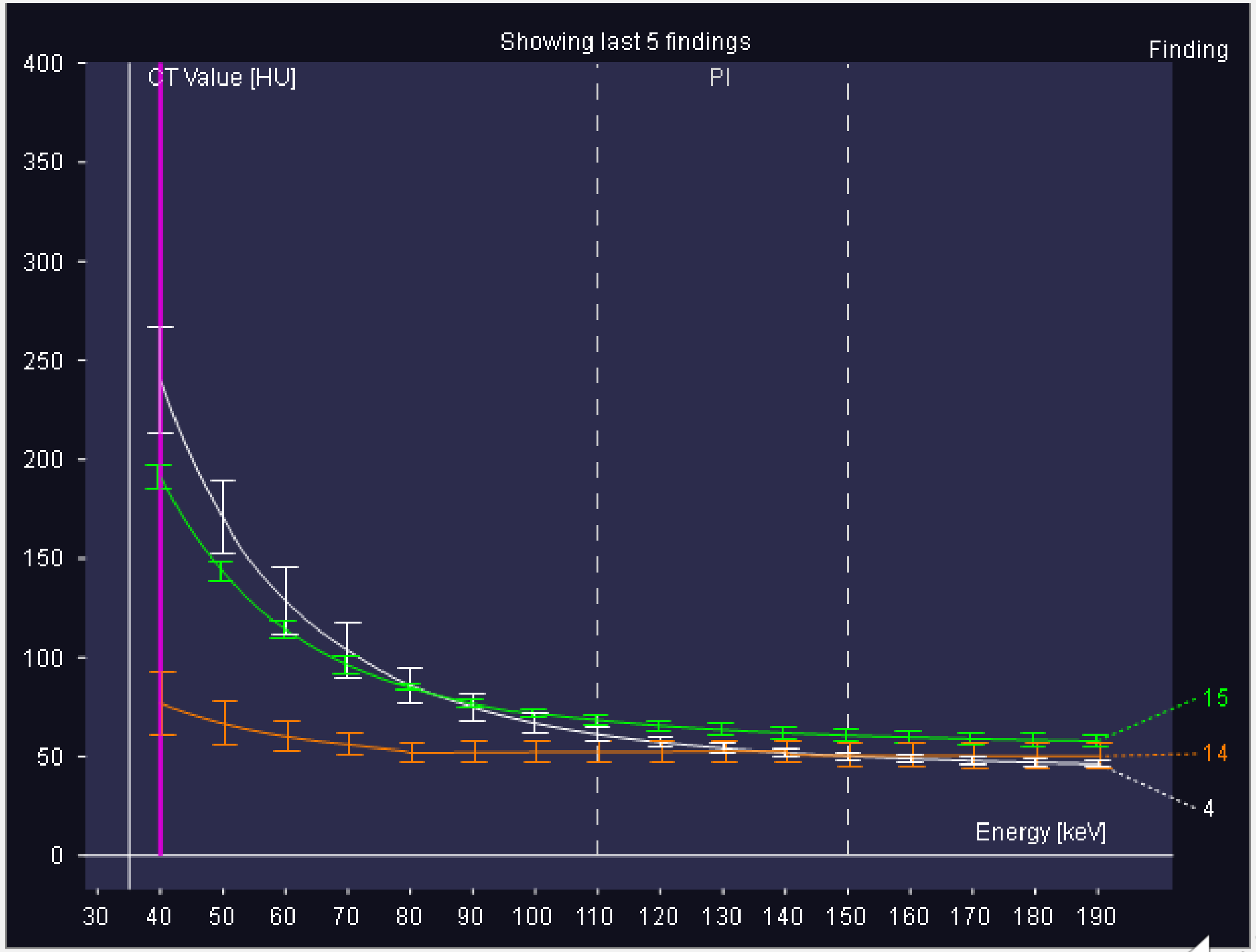
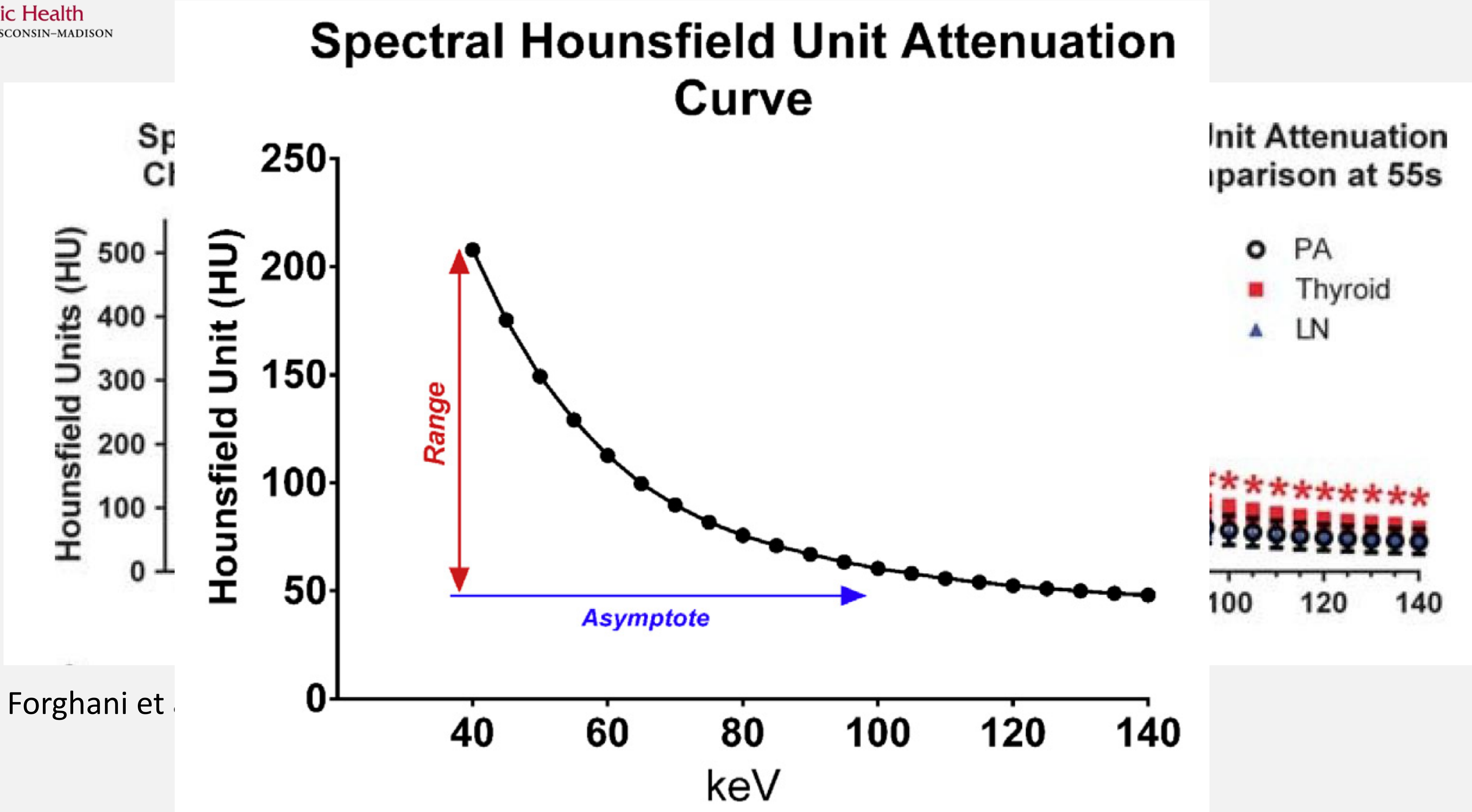
Spectral Hounsfield unit attenuation curves (SHUACs)





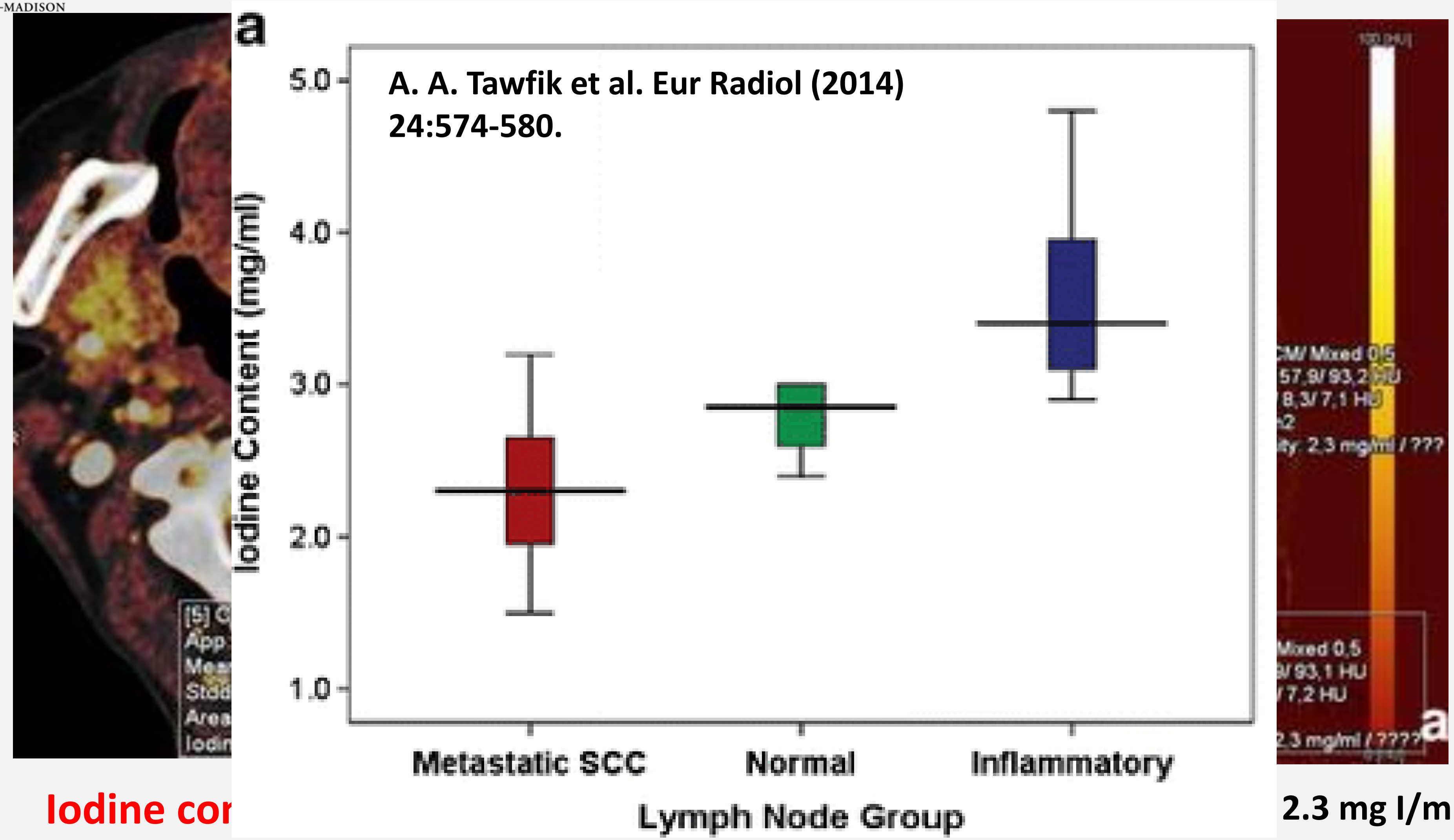
SHUACs – identifying malignant tissue



Forghani et

Srinivasan et al. J Comput Assist Tomogr. (2013) 37(5): 666–72.

Material decomposition – iodine map



A. A. Tawfik et al. Eur Radiol (2014) 24:574-580.

Iodine cor

2.3 mg I/ml

Roele, E.D., Timmer, V.C.M.L., Vaassen, L.A.A. et al. Curr Radiol Rep (2017) 5: 19.

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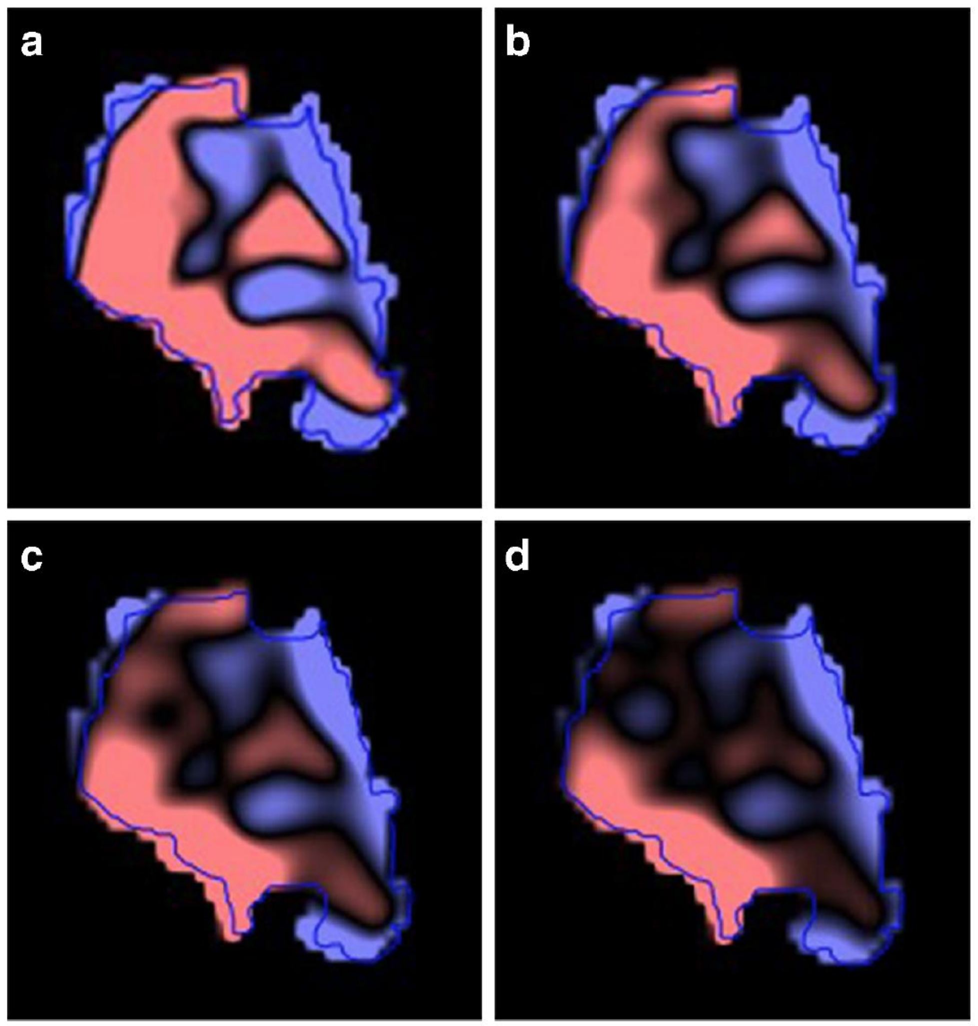
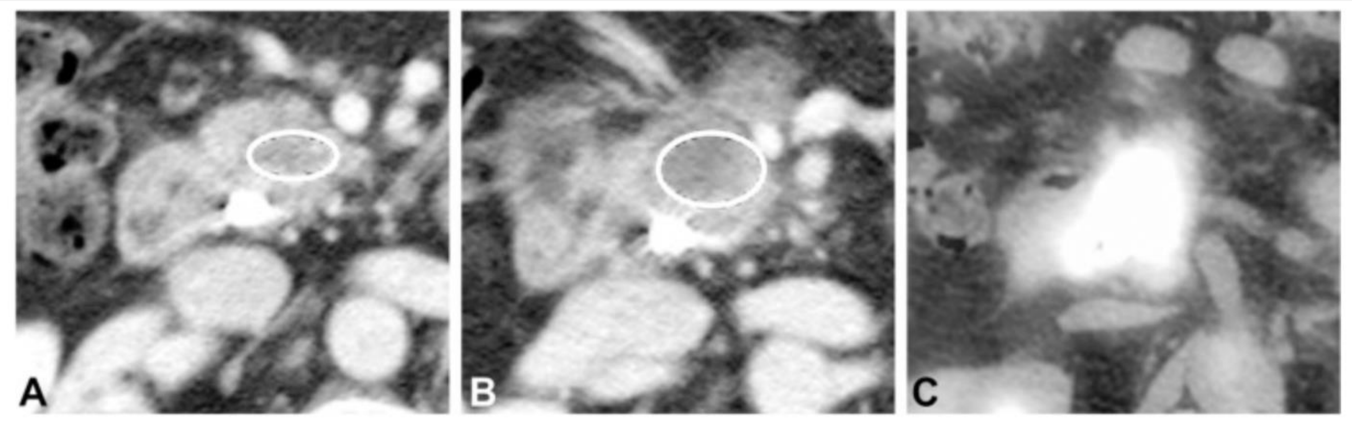
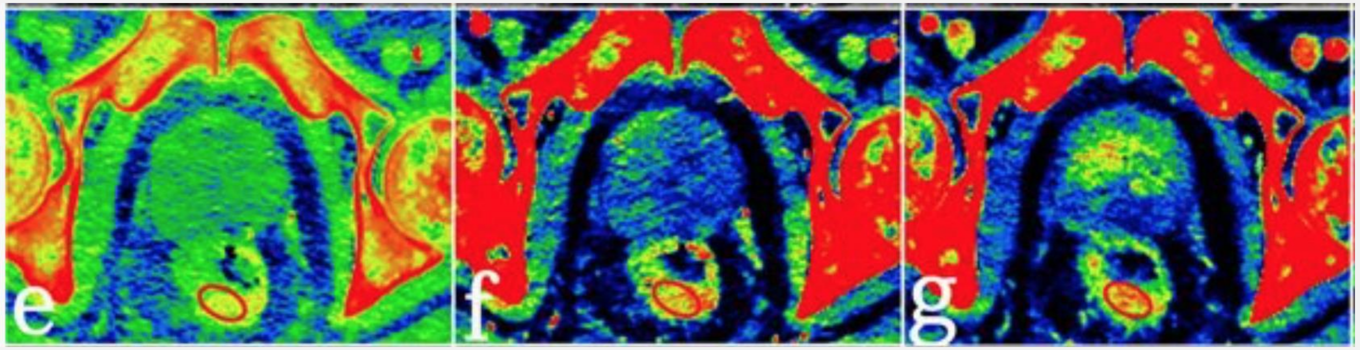
Incorporating multiple images to characterize tumor





Oldan et al. J Digit Imaging. (2014) 27(6): 824-32.



Wu et al. European Radiology. (2019) 29(7): 3782-3790.

Forghani et al. European Radiology (2019) 29:6172-6181.

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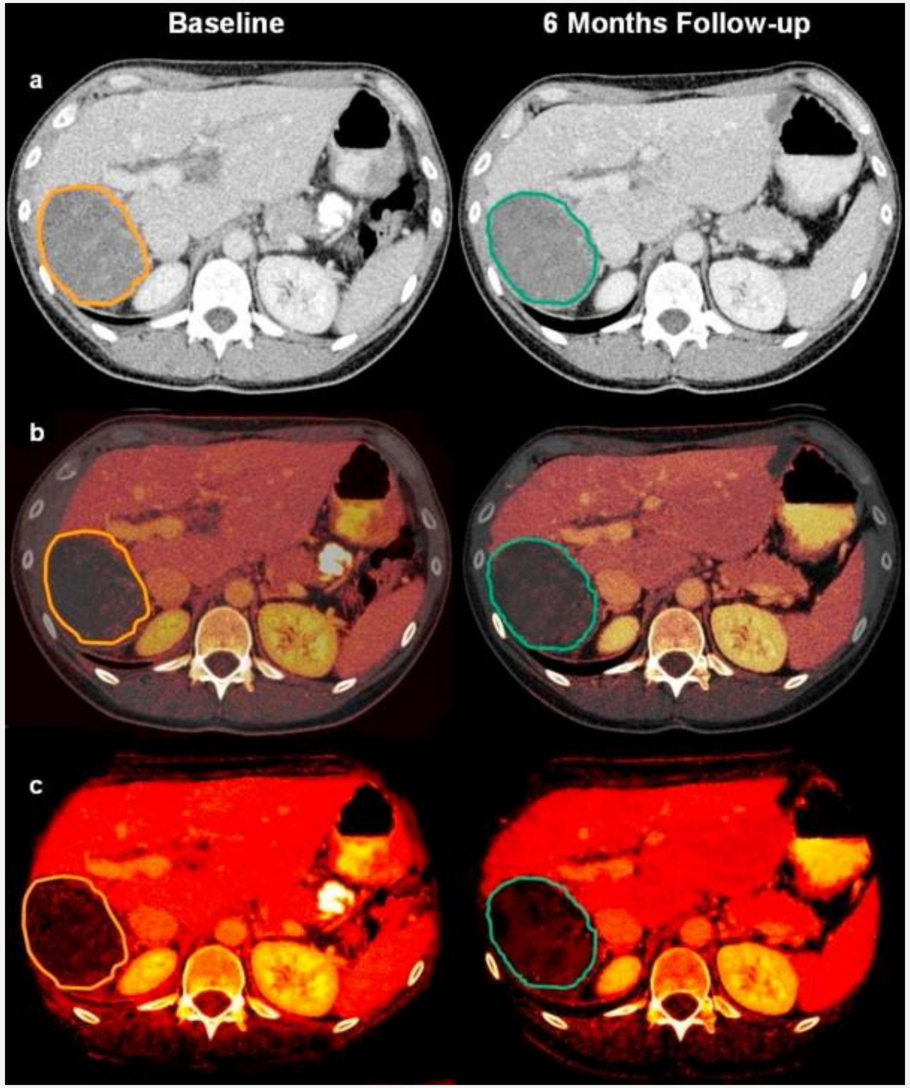
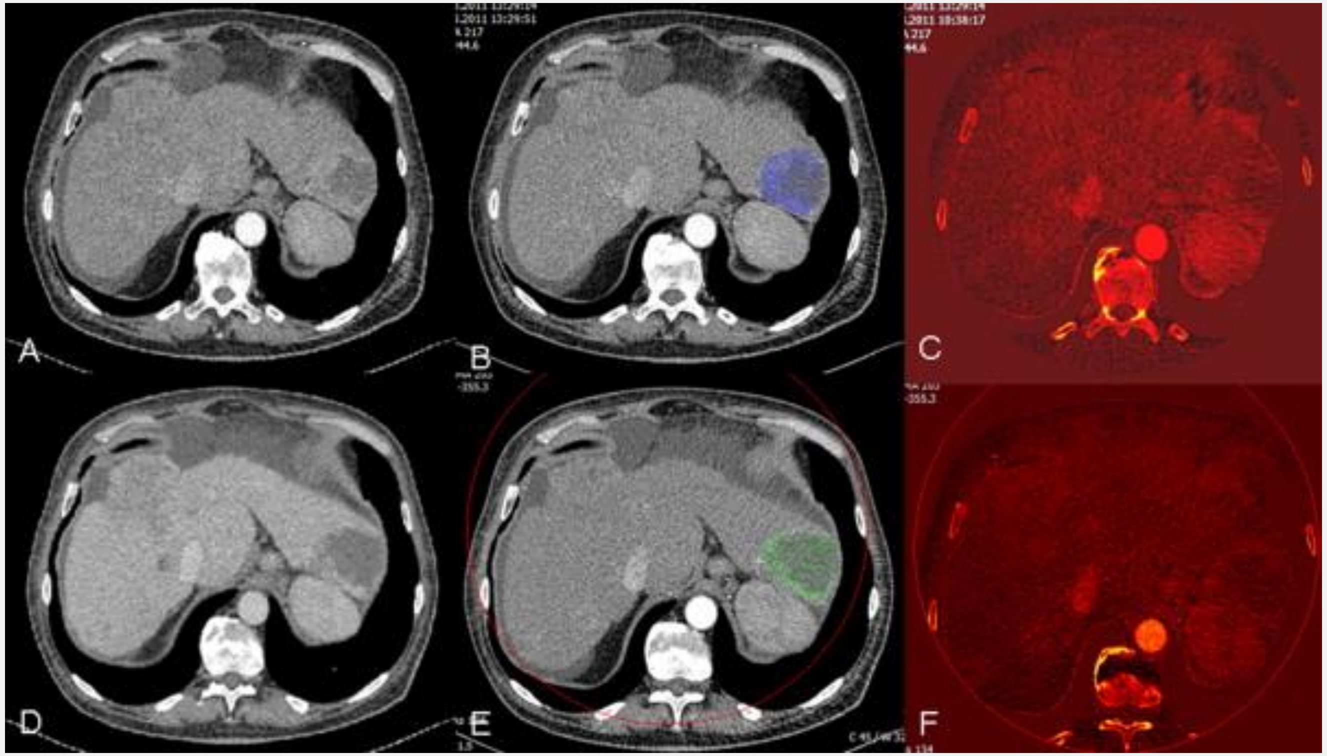
Radiation therapy applications:

Treatment response assessment

Treatment response with DECT iodine maps

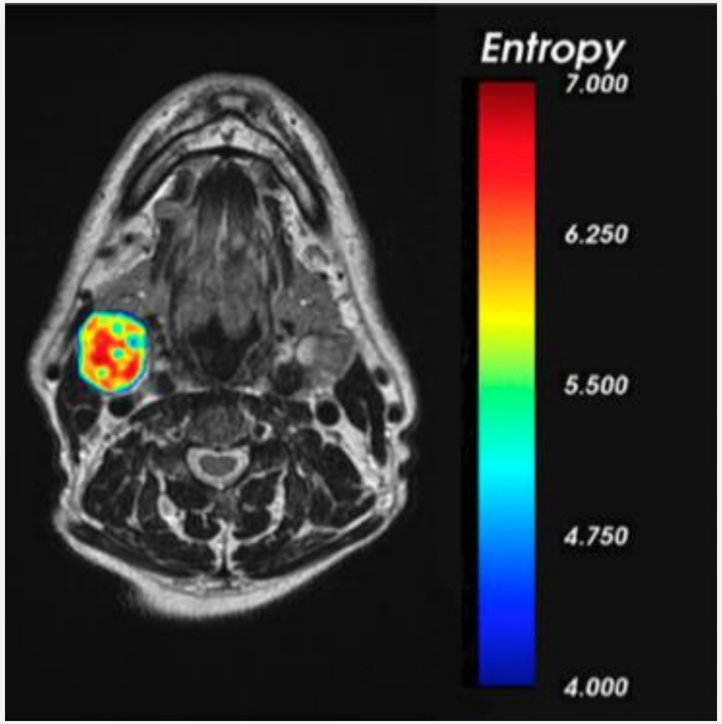




M. Meyer et al. European Journal of Radiology (2013) 82(6): 923-928.

X. Dai et al. European Journal of Radiology (2013) 82: 327-334.

Texture analysis in radiation therapy



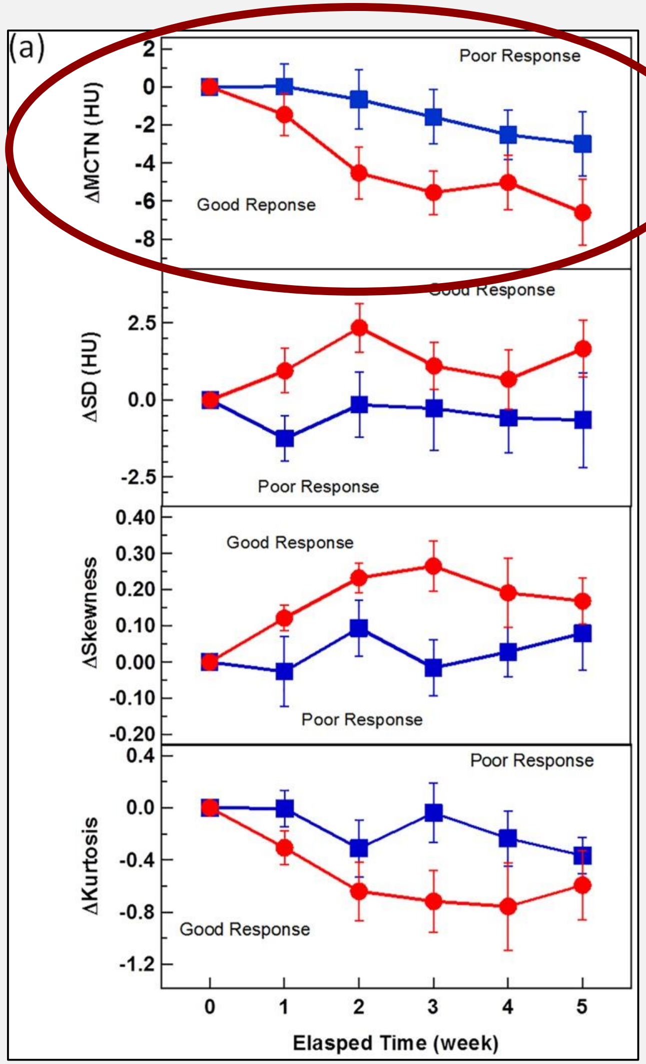
Elisa Scalco and Giovanna Rizzo. Br J Radiol (2017) 90: 20160642.

Table 3. Studies who have applied texture analysis in the context of radiotherapy

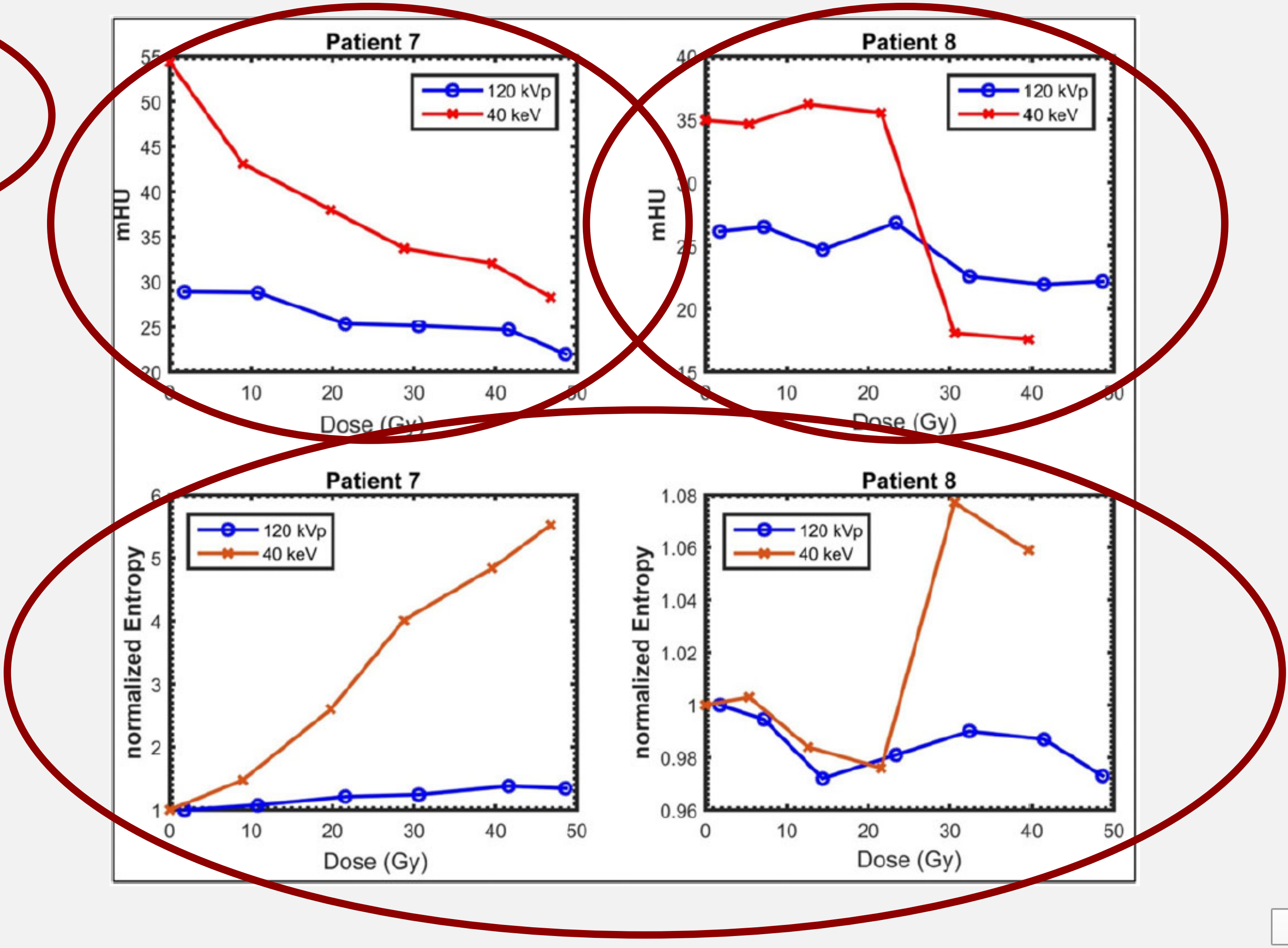
Radiotherapic aim	District	Imaging modalities	Treatment type	References (first author, year)
Radiation targeting in RT planning	Head and neck	PET/CT	IMRT	Yu et al, 2009[72,73]
	Prostate	CT	IMRT	Nailon et al, 2008[29]
Tumour response to treatment	Lung	PET	SABR	Pyka et al, 2015[82]
		PET	CRT	Cook et al, 2013[83]
		CT	SABR	Huynh et al, 2016[85]; Mattonen et al, 2014[79]; Mattonen et al, 2015[80]; Mattonen et al, 2016[81];
		CT	CRT	Coroller et al, 2016[84]
	Oesophagus	PET	CRT	Tixier et al, 2011[86]; Nakajo et al, 2016[87]; Yip, et al 2016[37]
		CT	CRT	Yip et al, 2014[88]
	Head and neck	PET	CRT	El Naqa et al, 2009[89]
		mp-MRI	CRT	Liu et al, 2016[90]; Scalco et al, 2016[91]
		DCE-MRI	IMRT	Jansen et al, 2016[63]
	Prostate	T2w-MRI	EBRT	Gnep et al, 2016[94]
	Rectum	PET	CRT	Bundschuh et al, 2014[95]
		T2w-MRI	CRT	De Cecco et al, 2015[96]
		mp-MRI	CRT	Nie et al, 2016[97]
	Brain	MRI	SRT	Nardone et al, 2016[99]
	Soft-tissue sarcoma	CT	CRT	Tian et al, 2015[98]
Radiation-induced effects on normal tissue	Lung	CT	SBRT	Mattonen et al, 2014[79]; Mattonen et al, 2015[80];
		CT	Oesophageal RT	Cunliffe et al, 2015[100]
	Parotid glands	Ultrasound	Head–neck RT	Yang et al, 2012[101]
		CT	IMRT	Scalco et al, 2013[102]; Scalco et al, 2015[104]; Pota et al, 2015[103]

CRT, chemoradiotherapy; DCE-MRI, dynamic contrast-enhanced MRI; EBRT, external beam radiotherapy; IMRT, intensity-modulated radiotherapy; mp-MRI, multiparametric MRI; PET, positron emission tomography; RT, radiotherapy; SABR, stereotactic ablative radiation therapy; SRT, stereotactic radiotherapy; T2w, T_2 weighted.

Treatment response with DECT texture features



Chen et al. PLOS ONE (2017) 12(6): e0178961.



Noid et al. Medical Physics (2018) 45: 4238 – 4245.

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Radiation therapy applications:

Normal tissue segmentation

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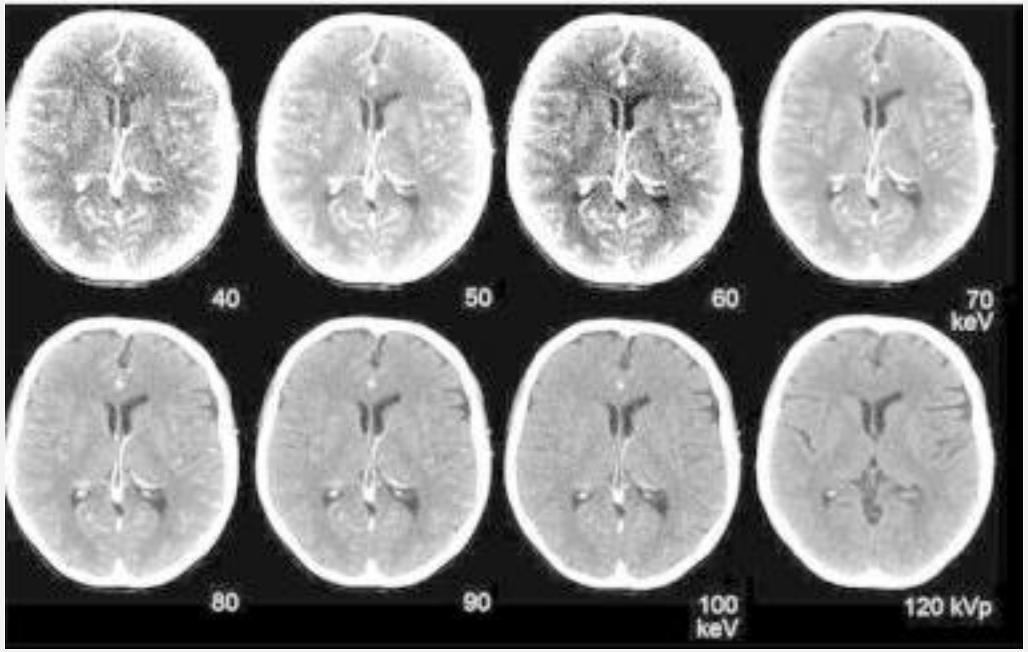
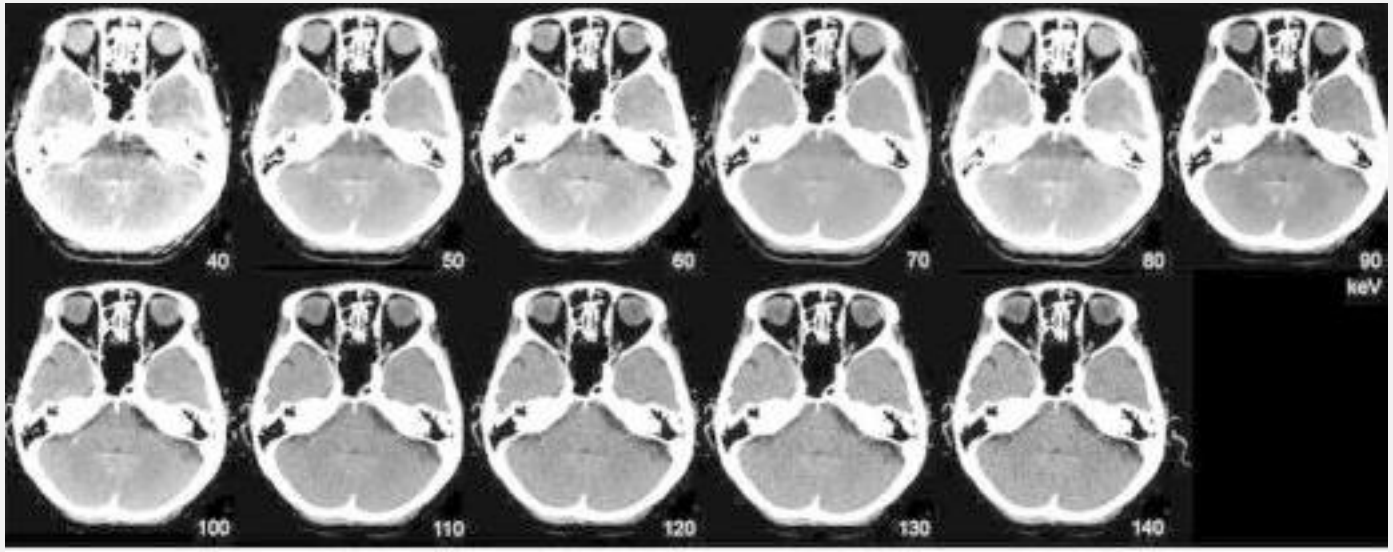
Normal tissue delineation



Supratentorial
white matter/basal ganglia

50 keV to 70 keV

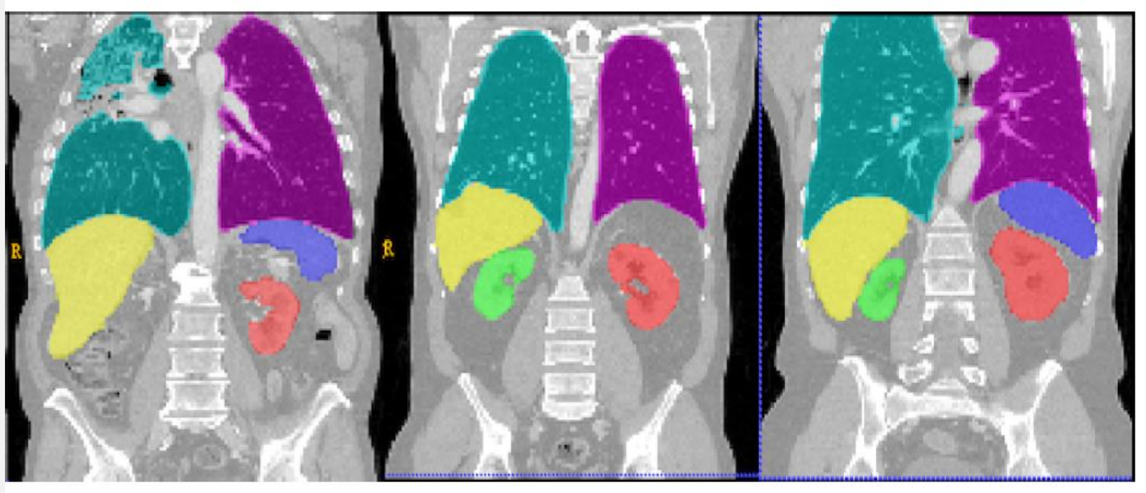
Postma et al. Dual-Energy CT: **What the Neuroradiologist Should Know.** Current Radiology Reports (2015) 3(5):16.



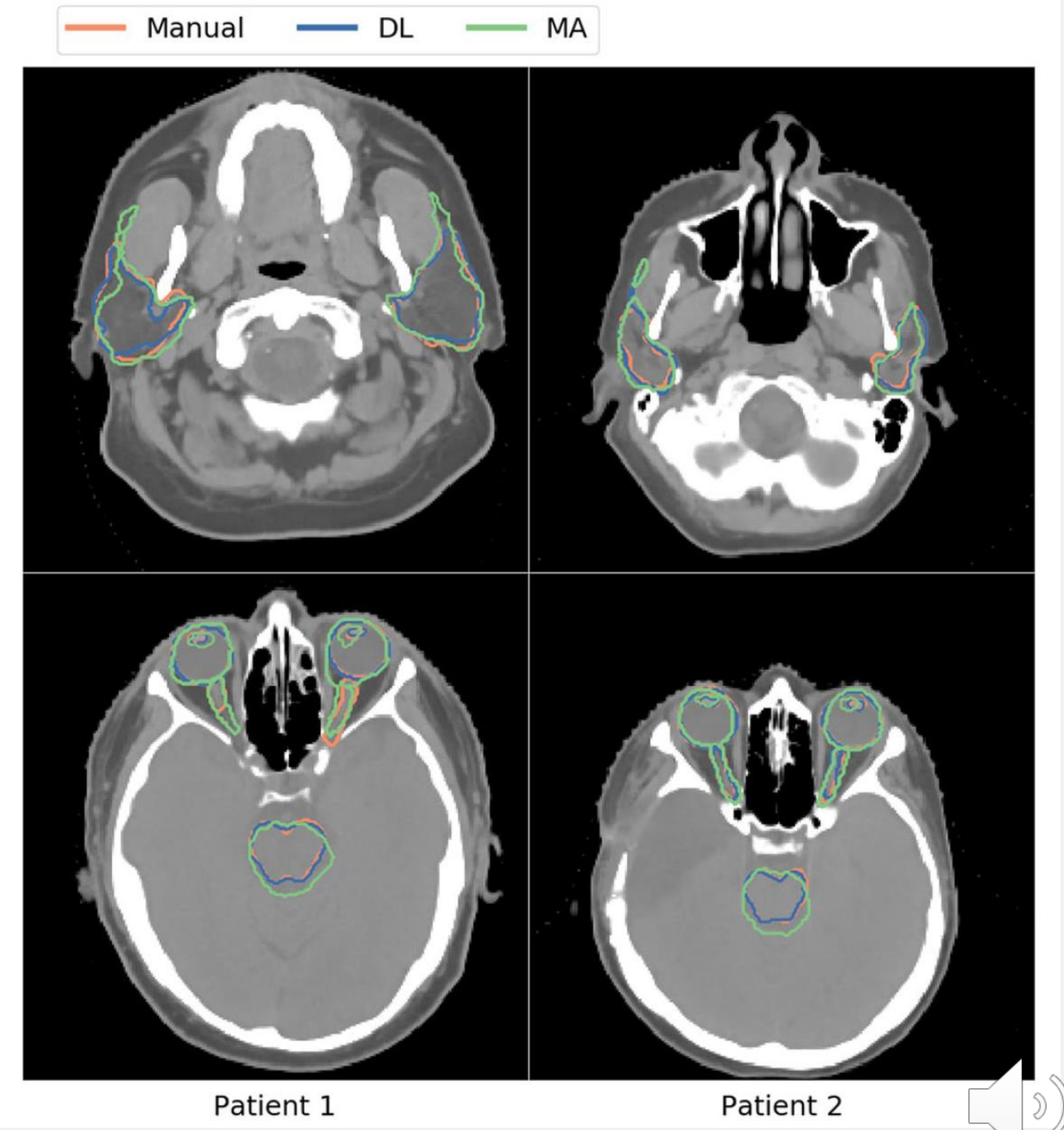
Posterior fossa

Higher energies

Normal tissue segmentation



Chen et al. 1st Conference on Medical Imaging with Deep Learning (MIDL 2018).



Van der Heyden et al. Scientific Reports (2019) 9 Article # 4126.

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Radiation therapy applications:

Functional normal tissue segmentation and toxicity

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Motivation for functional imaging in radiation therapy

- Typical radiation therapy treatment plans assess radiation dose to the entire lung volume
  - Mean lung dose, V5, V20, V30, etc.
- More than half of lung cancer patients have concomitant pulmonary disease
- Functional lung volume is a better metric then anatomical lung volume for predicting lung toxicities
- Need for accessible functional lung imaging techniques which can be incorporated in the the radiation therapy workflow

Houda Bahig et al. International Journal of Rad. Onc., Biology, Physics (2017) 99(1) 334-343.

Functional lung imaging: ventilation

Clinical Trail NCT02843568

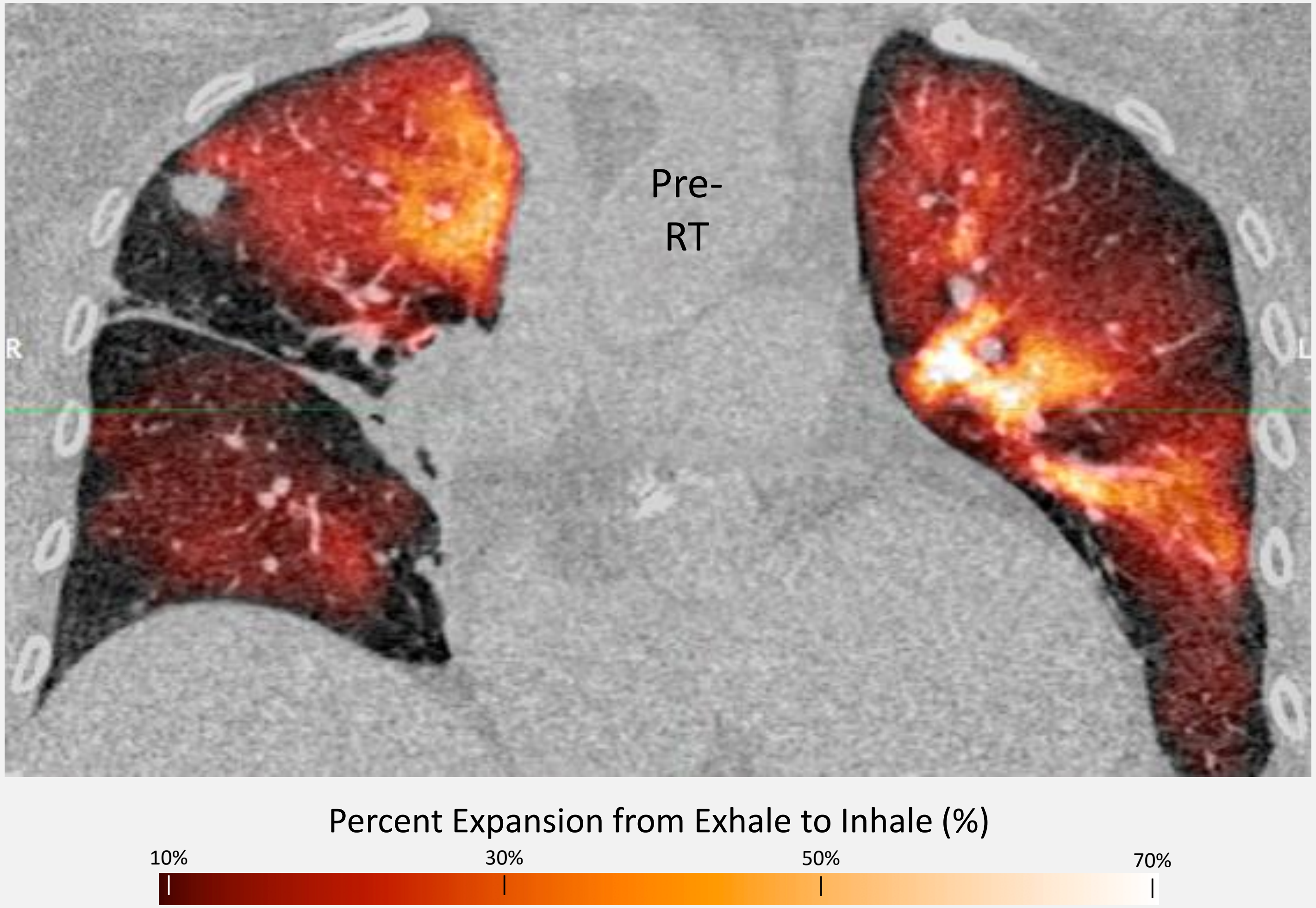

Image provided by Dr. John Bayouth

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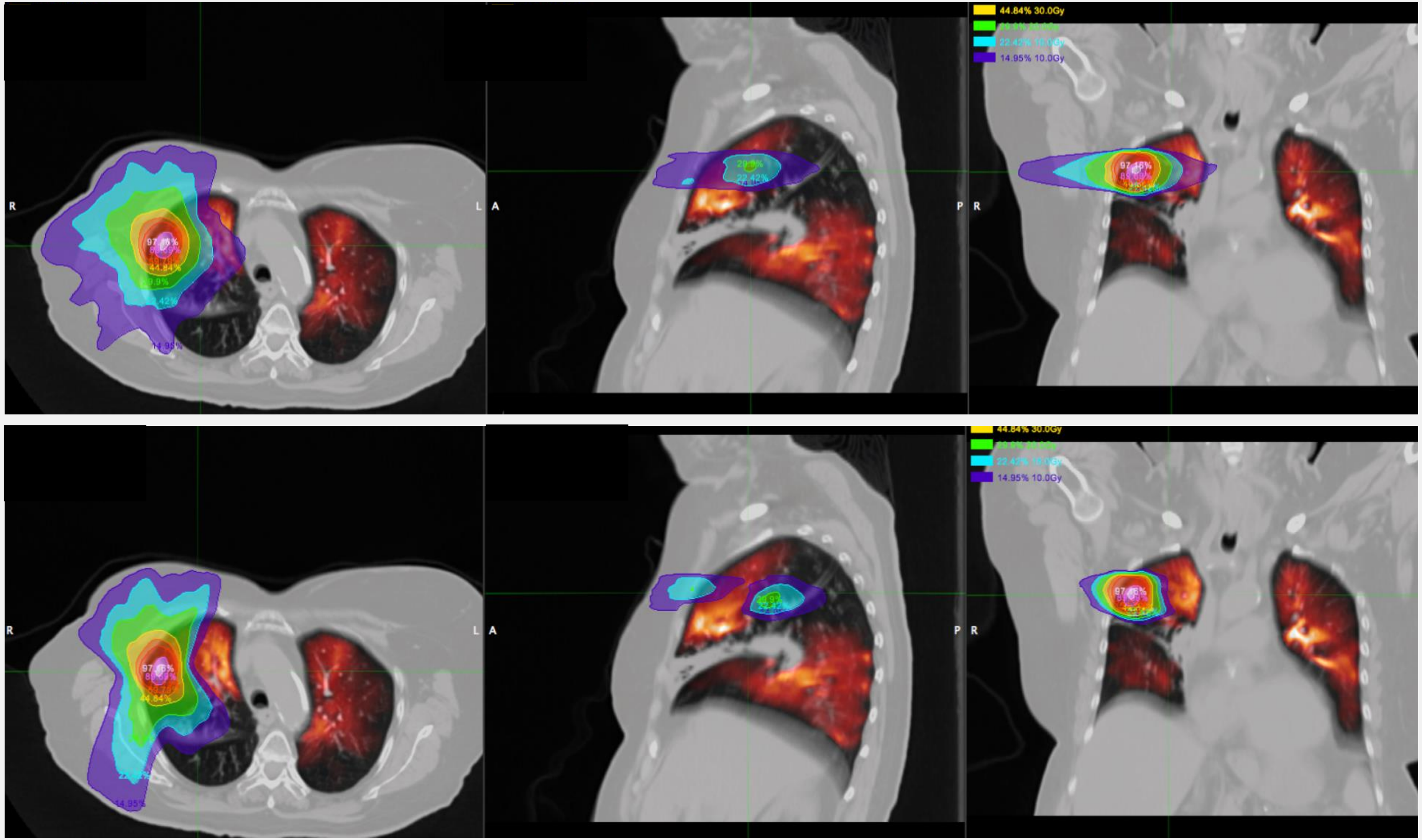
Functional lung treatment plans

Image provided by Dr. John Bayouth

Conventional Plan

Optimized Plan (spares high ventilation regions)



Clinical Trail NCT02843568 : Improving Pulmonary Function Following Radiation Therapy

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Preserving lung function post-RT

Clinical Trail: NCT02843568

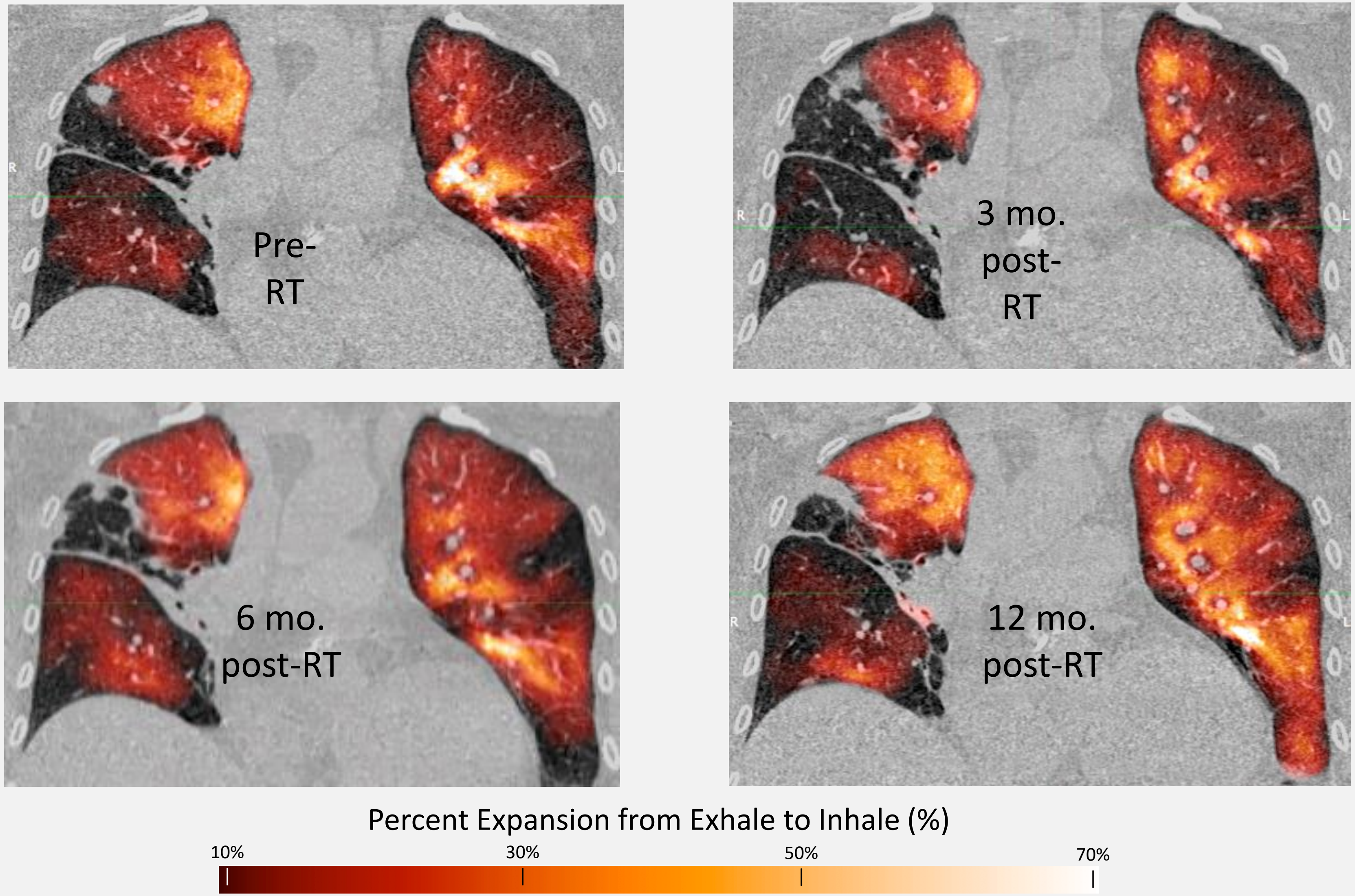

Image provided by Dr. John Bayouth

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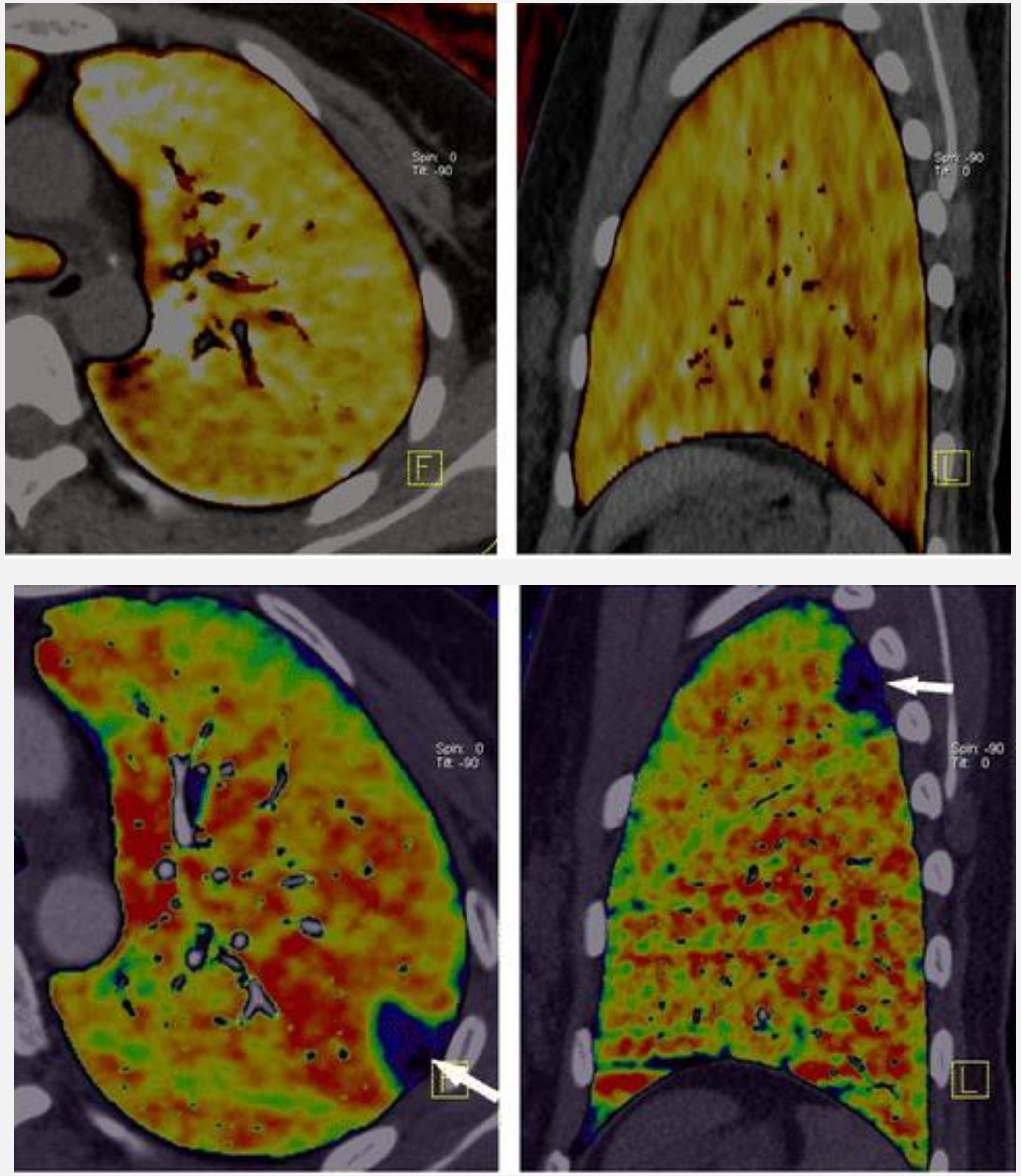
DECT-derived functional lung

Ventilation

Xenon
inhalation

Perfusion

Iodine
injection



Zhang, L.J., Zhou, C.S., Schoepf, U.J. et al. Eur Radiol (2013) 23: 2666.

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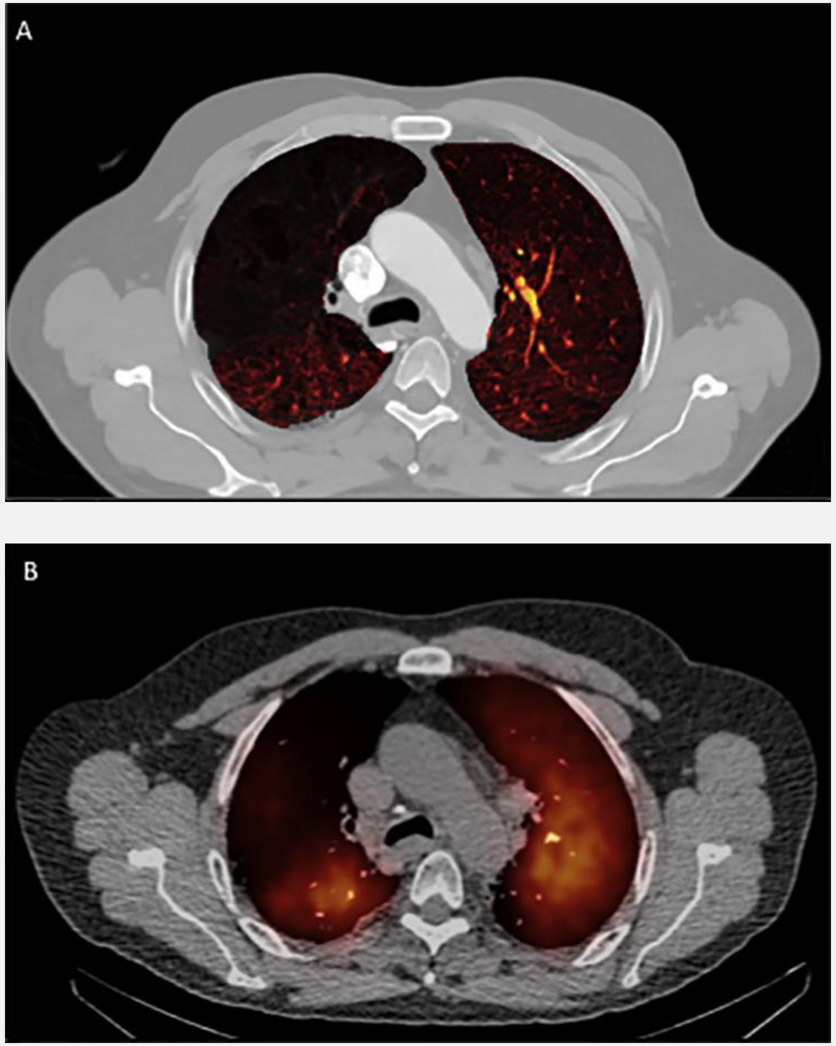
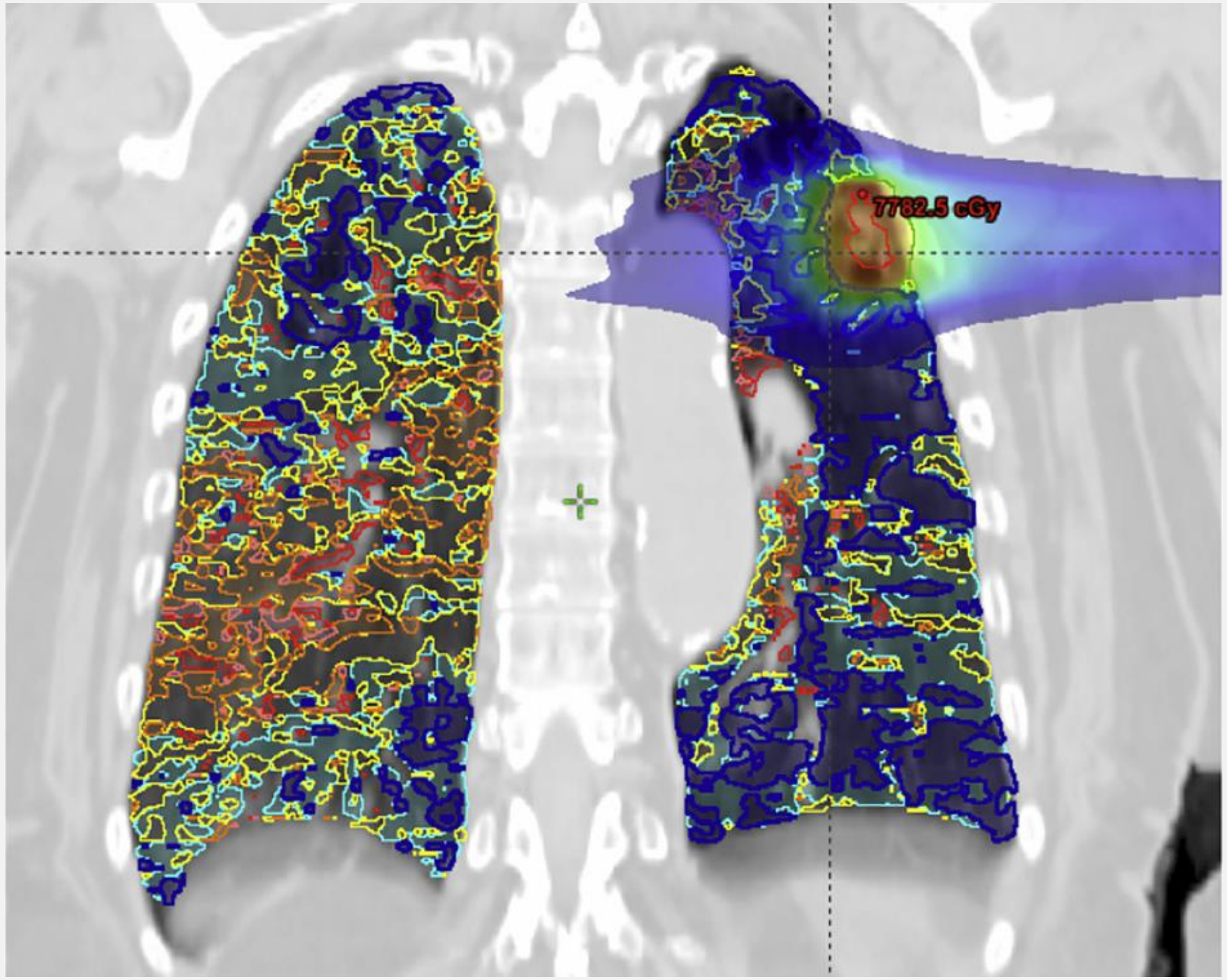
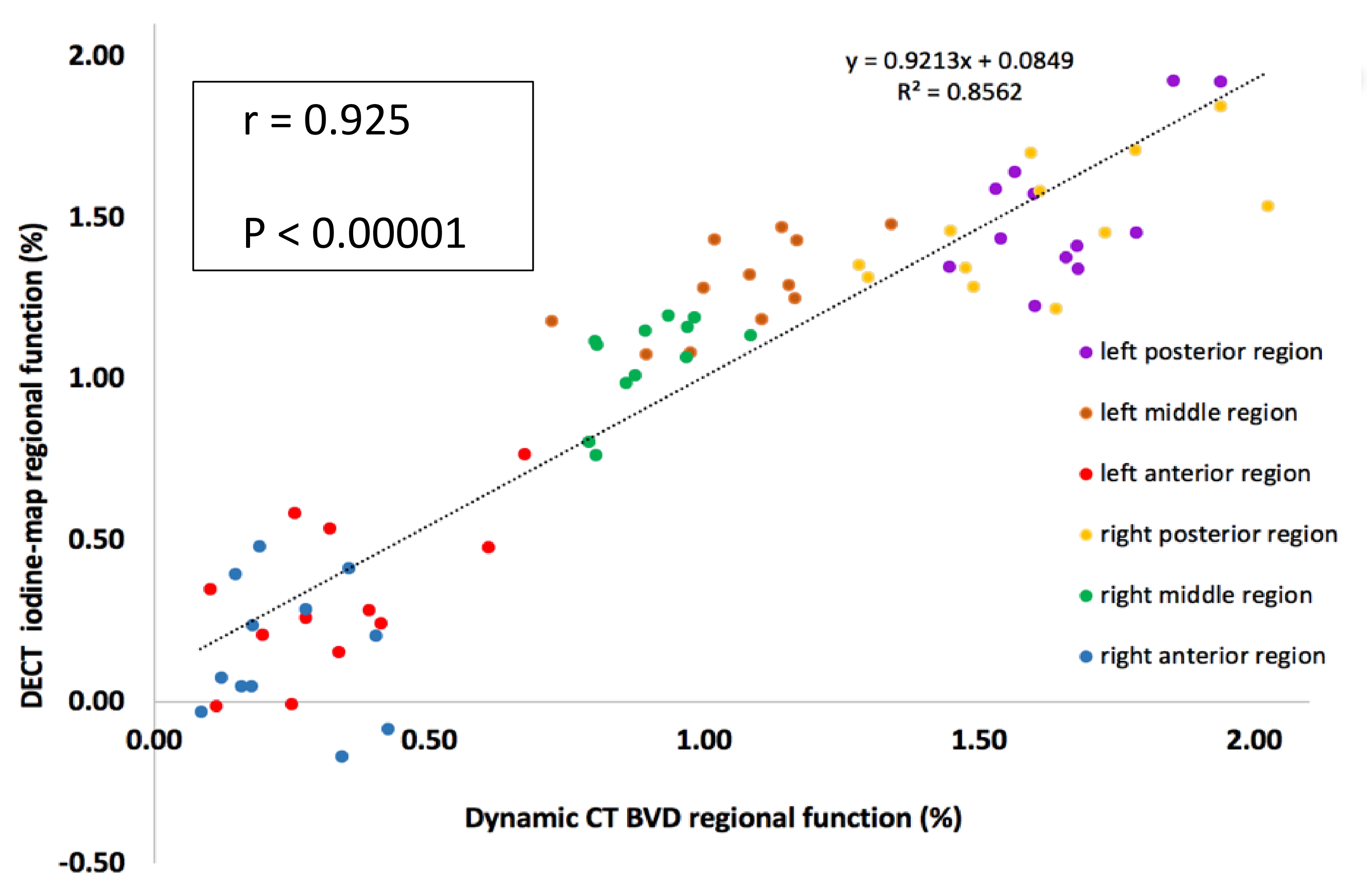
Lung perfusion using dual-source DECT





Houda Bahig et al. International Journal of Rad. Onc., Biology, Physics (2017) 99(1): 334-343.

Lung perfusion using split-filter DECT



Jessica Miller et al. 2019 Annual Meeting of the American Association of Physicists (Abstract #: WE-AB_221AB-4).

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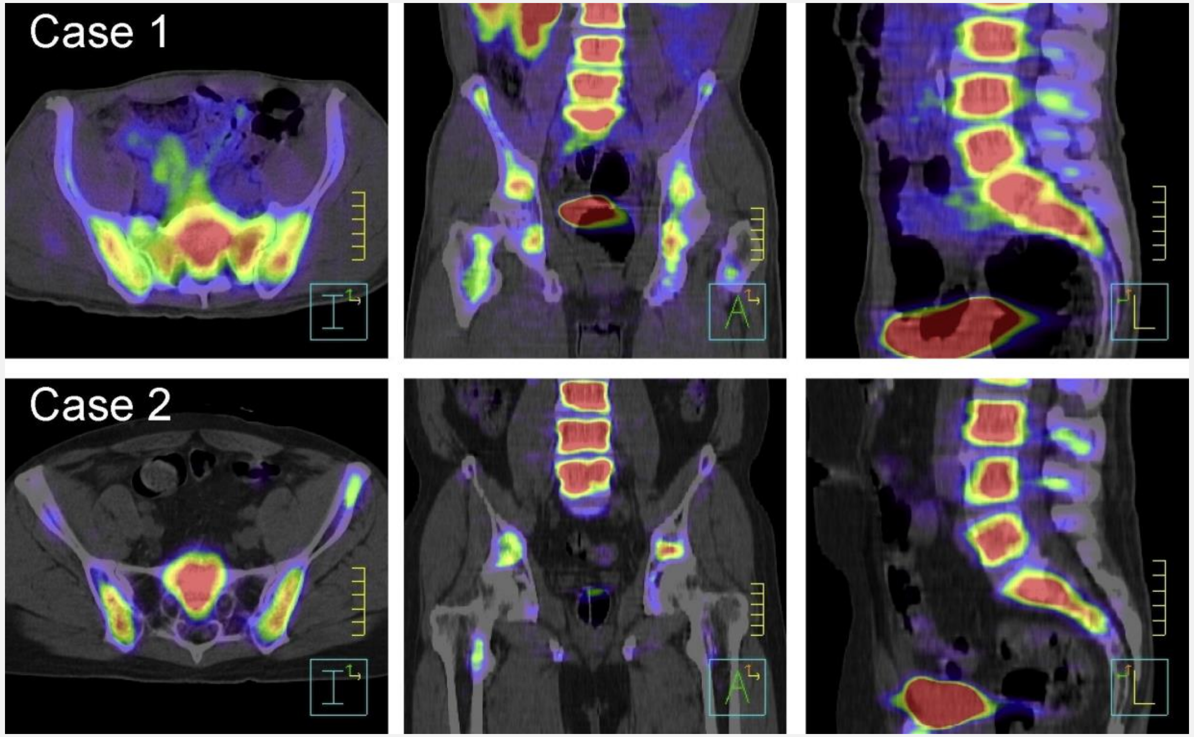
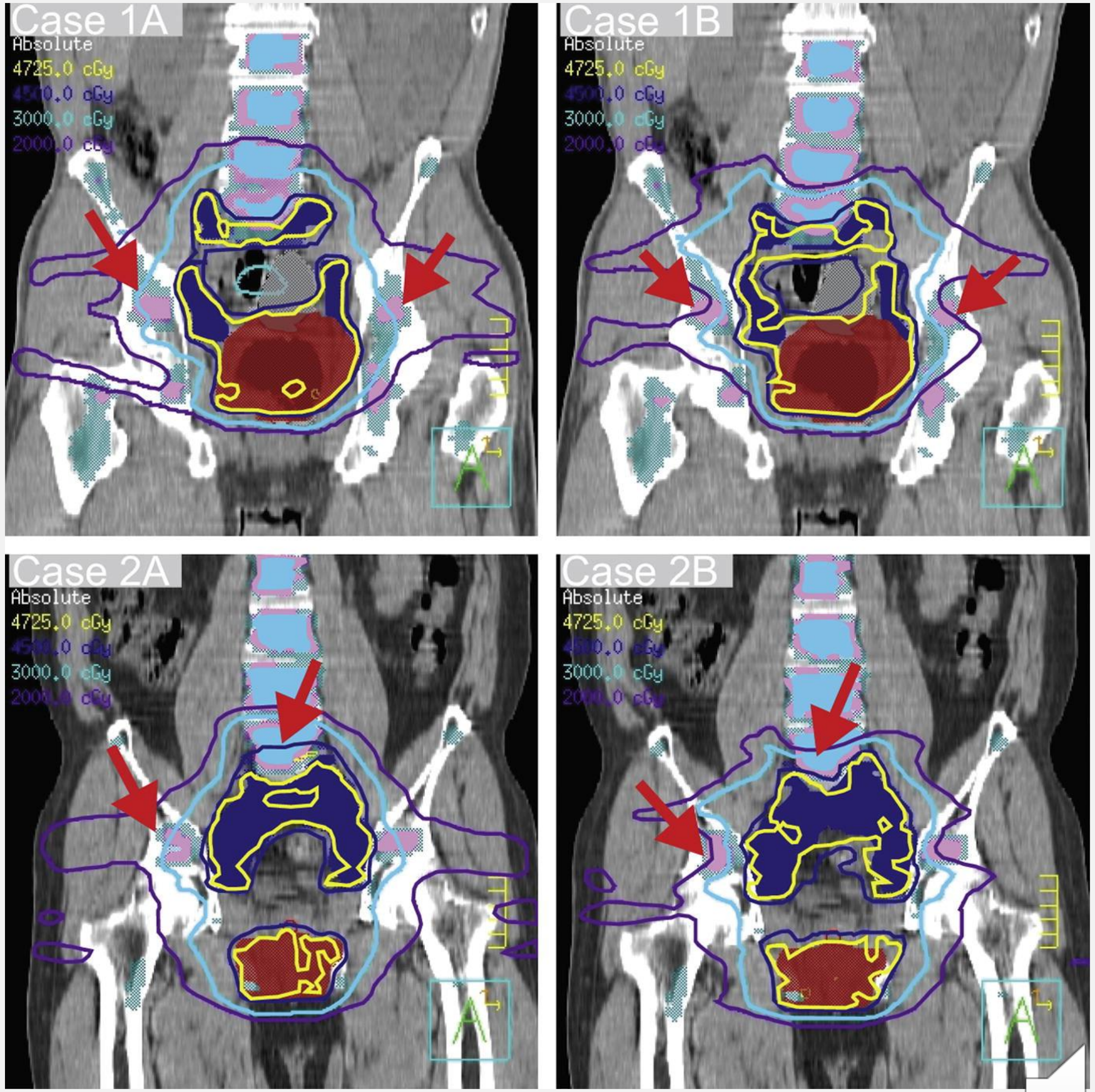
Functional bone marrow



Conventional

Functional



Sarah McGuire et al. Radiotherapy and Oncology (2011) 99(1): 49-54.

DECT-derived functional bone marrow

Taiki Magome et al. Int J Radiation Oncol Biol Phys (2016) 96(3): 679-687.

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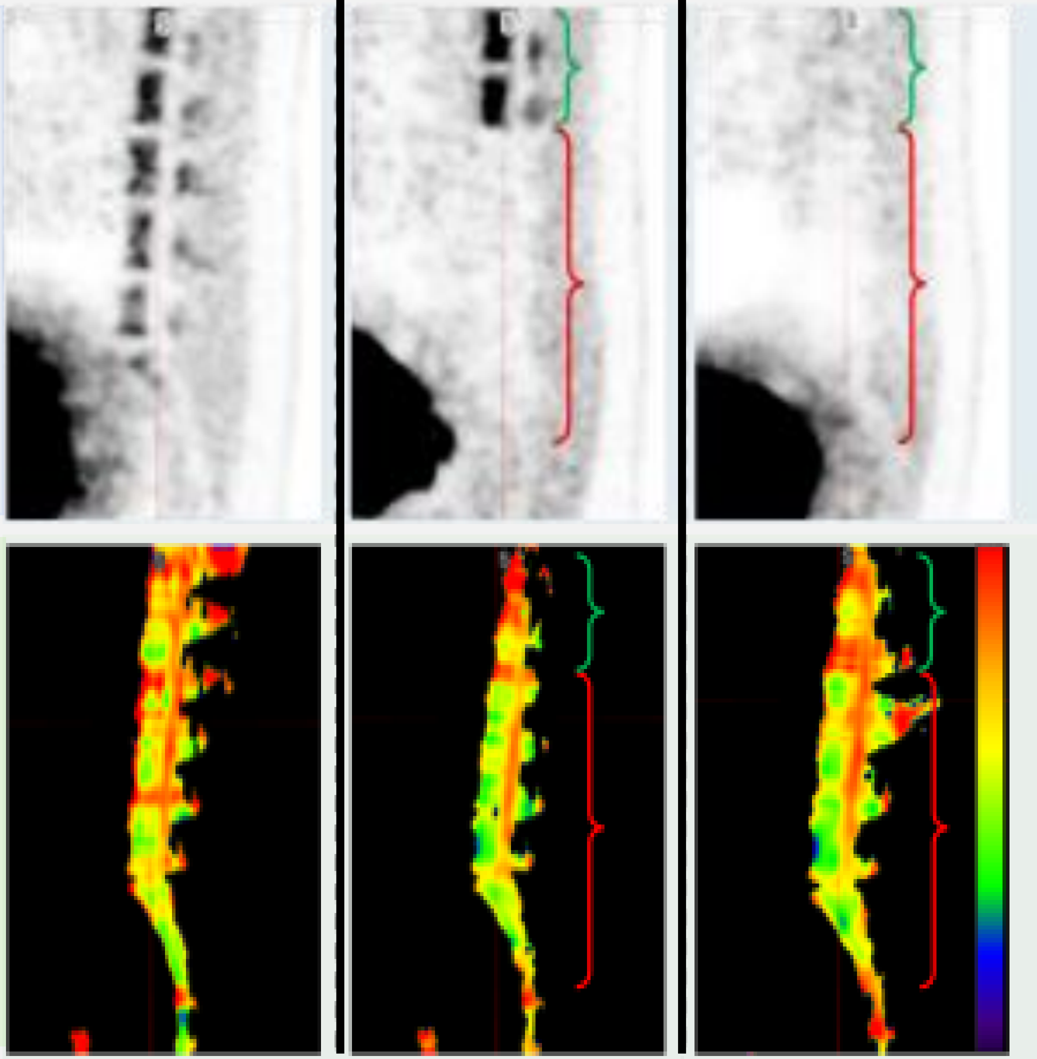
Radiation-induced changes to active bone marrow

	Pre-treatment	1 week post-treatment	4 weeks post-treatment
FLT PET			
Virtual non-calcium (DECT) HU-map			



Michael Lawless et al. 2020 Joint AAPM/COMP Virtual Meeting (Abstract #: TU-CD-TRACK 2-13).

Qihui Lyu et al. 2020 Joint AAPM/COMP Virtual Meeting (Abstract #: TH-CTRACK 1-5).

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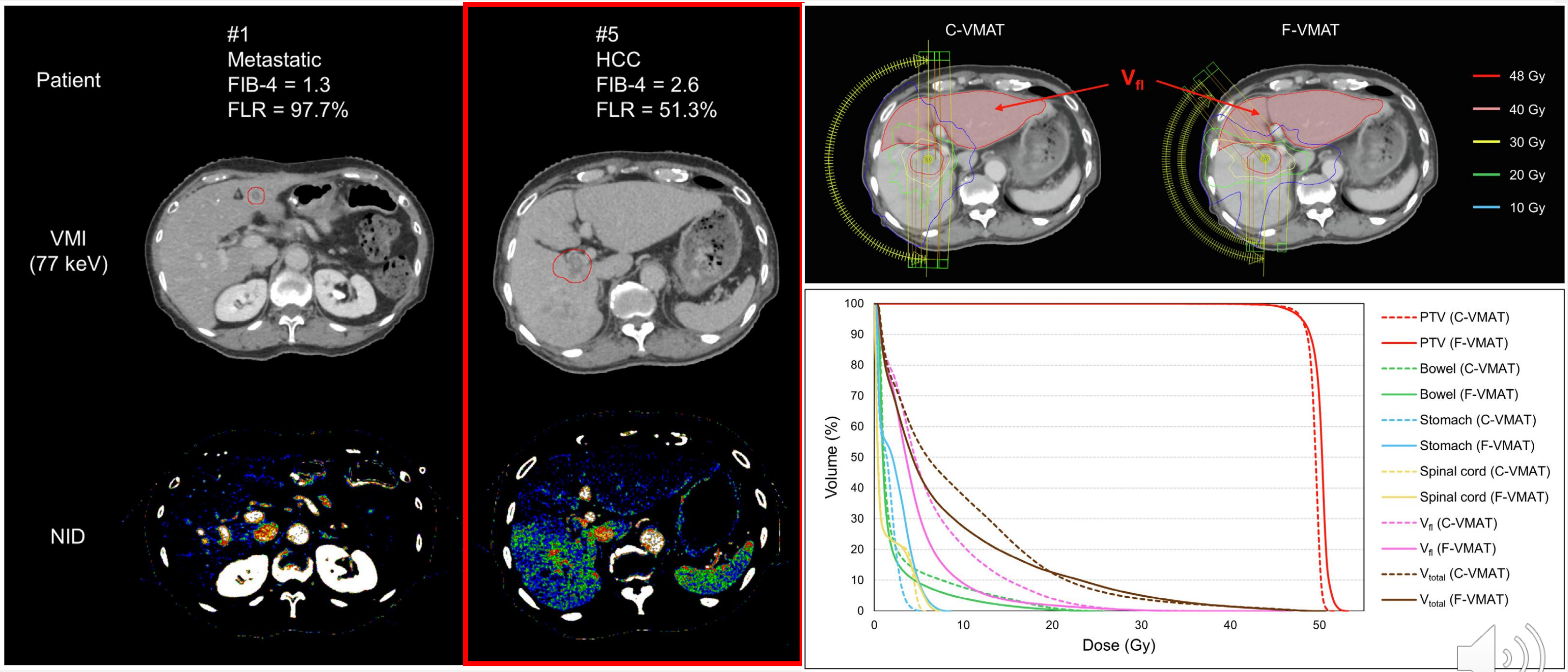
DECT-derived functional liver tissue



Shingo Ohira et al. Radiotherapy and Oncology (2020)v145 56-62.

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Conclusions

- Dose calculation accuracy
- Tumor identification, characterization, and delineation
- Treatment response assessment
- Normal tissue segmentation
- Functional normal tissue toxicities

Thank you

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Dr. Ke Sheng
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Gammex Collaborators

Dr. Kenneth Ruchala