

Quantitative CT/MRI for Adaptive Radiotherapy

X. Allen Li

Professor and Chief Physicist

WE-DE-FS1-0 (Wed, Aug 2, 2017) 10:45AM, Room: Four Seasons 1,
AAPM 2017



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Adaptive RT

Key:
To detect treatment response As Early As
Possible!!!

Solution: Quantitative Imaging

BGRT: Biologically guided radiation therapy—The future is fast
approaching!

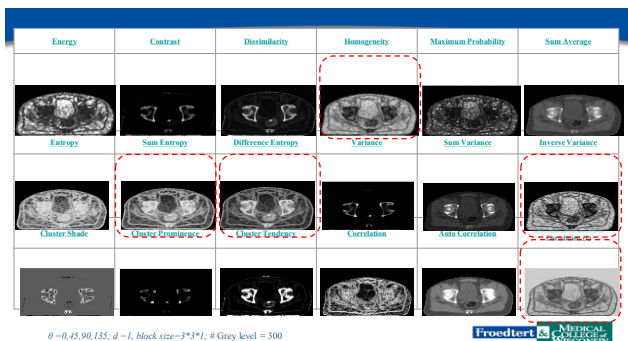
Robert D. Stewart
Robert D. Stewart, PhD, University of Wisconsin, 1300 University Avenue, Madison, WI 53706
X. Allen Li
Department of Radiation Oncology, Medical College of Wisconsin, 8700 Watertown Place, Brook
field, WI 53005
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published 15 September 2007)

Imaging is Data ! (not just picture)

Quantitative - Radiomics

- ❖ Extracting higher dimensional data from images through advanced imaging processing and analysis tools
- ❖ Mining these data, that extend beyond what is visible to human eye, for improved diagnosis and/or prognosis decision
- ❖ Available software tools:
IBEX, Amira, MaZda, CGITA, PET-STAT
Radiomics (www.oncoradiomics.com), TexRad (www.TexRad.com)
.....many in-house packages

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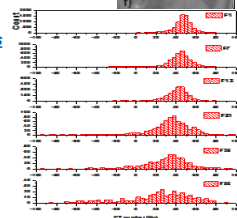
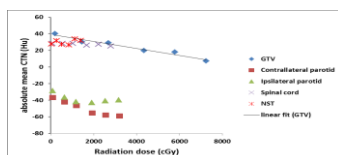


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Computed tomography number changes observed during computed tomography-guided radiation therapy for head and neck cancer.

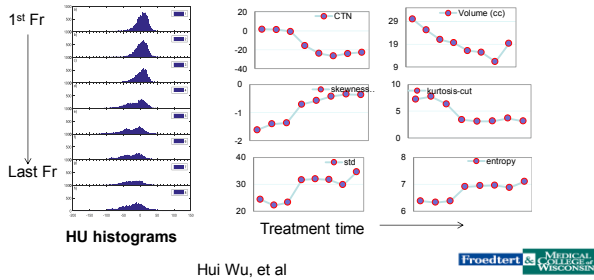
Feng M, Yang C, Chen X, Xu S, Moraru I, Lang J, Schultz C, Li XA.
 Int J Radiat Oncol Biol Phys. 2015 Apr 1;91(5):1041-7. doi: 10.1016/j.ijrobp.2014.12.057.

Analyzed daily CT during IGRT with CT-on-Rails



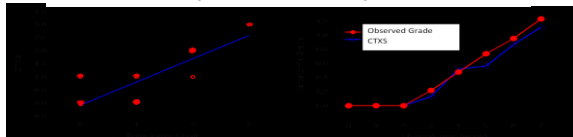
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Parotid Glands



Prediction of acute xerostomia

$$CTXS(\Delta V, \Delta MCTN) = \begin{cases} 0 & (\Delta V \leq 60\%) \\ 1 & (60\% < \Delta V \leq 75\%) \\ 2 & (75\% < \Delta V) \end{cases} + \begin{cases} 0 & (\Delta MCTN \leq 9HU) \\ 1 & (9 < \Delta MCTN \leq 15HU) \\ 2 & (\Delta MCTN > 15HU) \end{cases}$$

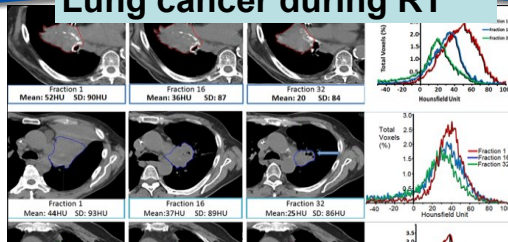


Data: 65 patients with HN cancers

- Henan Cancer Hospital (Dr. Wu)
- Sun Yat-sen University Cancer Center (Drs. Yang, Tao, Deng, Xia)
- Medical College of Wisconsin (Drs. Chen, Li)

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Lung cancer during RT



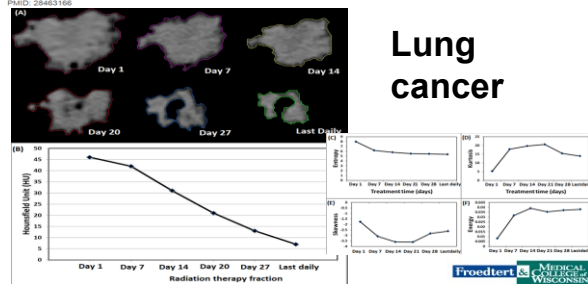
Early Assessment of Treatment Responses During Radiation Therapy for Lung Cancer Using Quantitative Analysis of Daily Computed Tomography

Paul J, Yang C, Wu H, Tai A, Dalah E, Zheng C, Johnstone C, Kong FM, Gore E, Li XA. Int J Radiat Oncol Biol Phys. 2017 Jun 1;98(2):463-472. doi: 10.1016/j.ijrobp.2017.02.032. Epub 2017 Feb 21. PMID: 28463166

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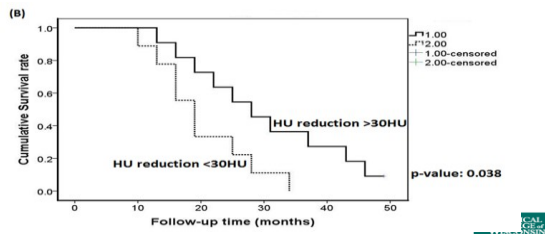
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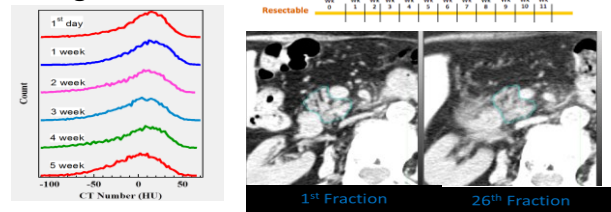


Early Assessment of Treatment Responses During Radiation Therapy for Lung Cancer Using Quantitative Analysis of Daily Computed Tomography.

Paul J, Yang C, Wu H, Tai A, Dalah E, Zheng C, Johnstone C, Kong FM, Gore E, Li XA. Int J Radiat Oncol Biol Phys. 2017 Jun 1;98(2):463-472. doi: 10.1016/j.ijrobp.2017.02.032. Epub 2017 Feb 21. PMID: 28463166



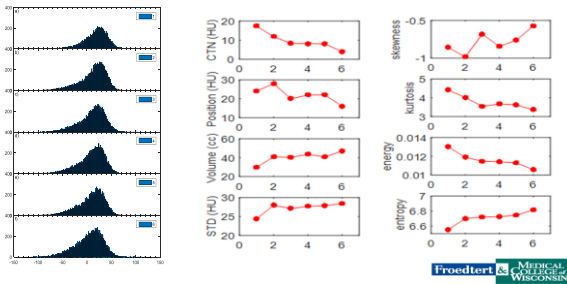
Pancreatic tumor during chemo-RT



Assessment of treatment response during chemoradiation therapy for pancreatic cancer based on quantitative adomic analysis of daily CTs: An exploratory study.

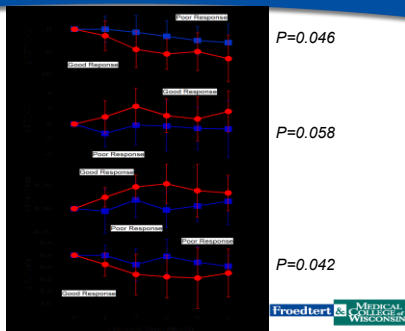
Chen X, Oshima K, Schott D, Wu H, Hall W, Song Y, Tao Y, Li D, Zheng C, Knechtges P, Erickson B, Li XA. PLoS One. 2017 Jun 2;12(6):e0178961. doi: 10.1371/journal.pone.0178961. eCollection 2017.

A sample pancreatic cancer case

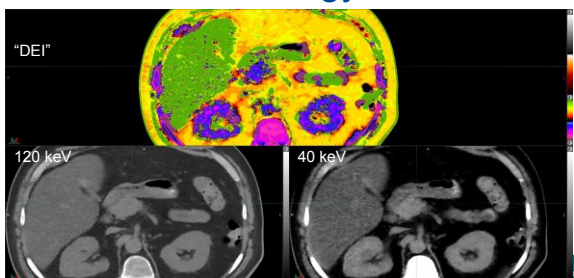


Correlation with pathological response

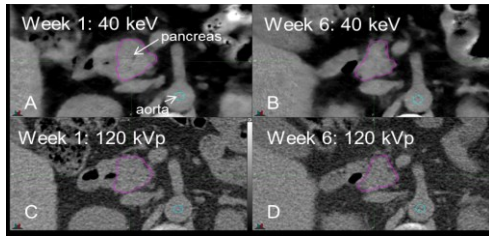
20 patients



Dual-energy CT



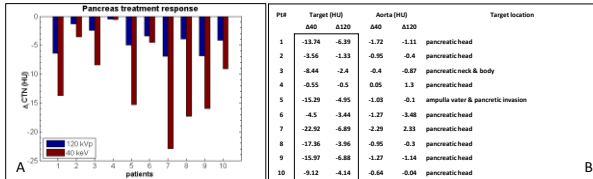
DECT at first and last weeks of RT



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DECT for treatment response

Pancreas

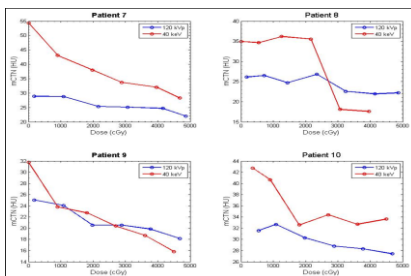


A The change in the mean CTN between the first and last week of treatment for the 10 pancreas patients in the study as measured at 120 kVp and 40 keV. B. A table summarizing the mean CTN change (HU) in the target and aorta along with the target location for each patient.

e-Poster : SU-F-FS4-2, Noid, Li, et al

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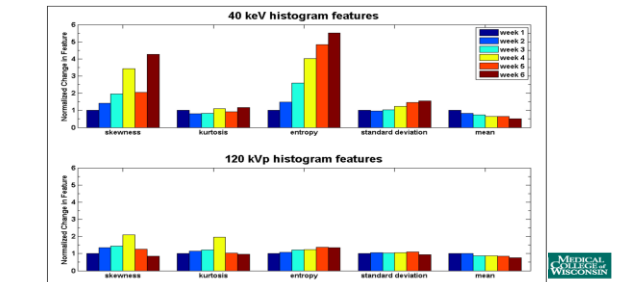
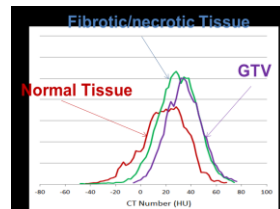
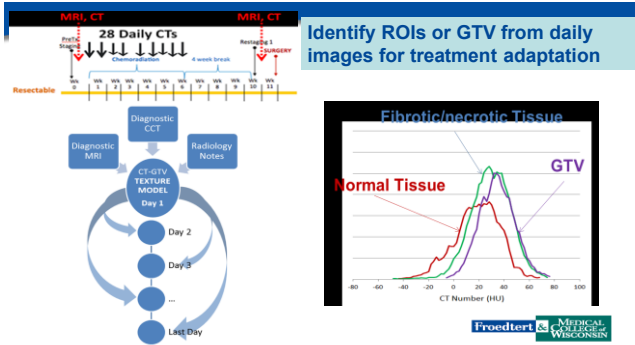
DECT for Pancreas treatment response



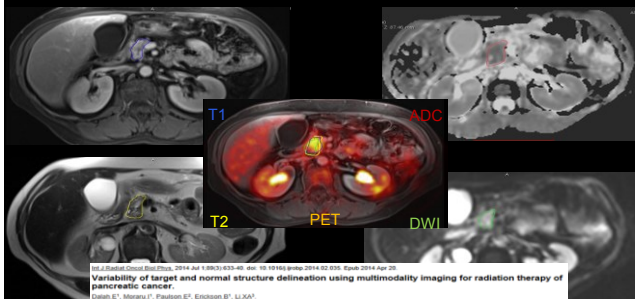
- Patient dependent CTN effect
- The change is larger in 40 keV than it is 120 kVp, amplifying treatment response signal

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DEPT 6

[illegible]

Multimodality imaging for GTV definition

[illegible]

Pancreas

Arterial T1-weighted
Resectable

Arterial T1-weighted
Unresectable

DWI

Medical Physics 42, 28 (2015); doi: 10.1118/1.4989099

Comprehensive MRI simulation methodology using a dedicated MRI scanner in radiation oncology for external beam radiation treatment planning

Eric S. Paulson, Beth Erickson, Chris Schultz, and X. Allen Li

Recommendations for MRI-based contouring of gross tumor volume and organs at risk for radiation therapy of pancreatic cancer.

Heerkens HD, Hall WA, Li XA, Knechtges P, Dalah E, Paulson ES, van den Berg CA, Meijer GJ, Koay EJ, Crane CH, Aitken K, van Vulpen M, Erickson BA.

Pract Radiat Oncol. 2017 Mar - Apr;7(2):126-136. doi: 10.1016/j.prro.2016.10.006. Epub 2016 Oct 17.

Model building

Texture analysis

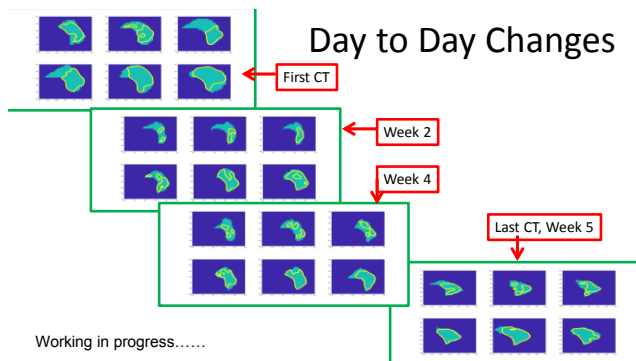
Classifier training and evaluation

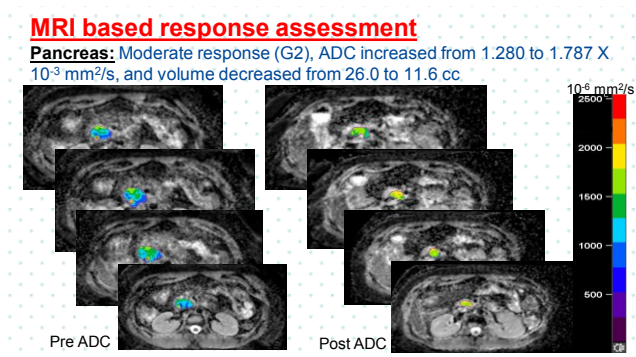
E-Poster:
MO-RPM-GePD-JT-4,
Schott, Li,....

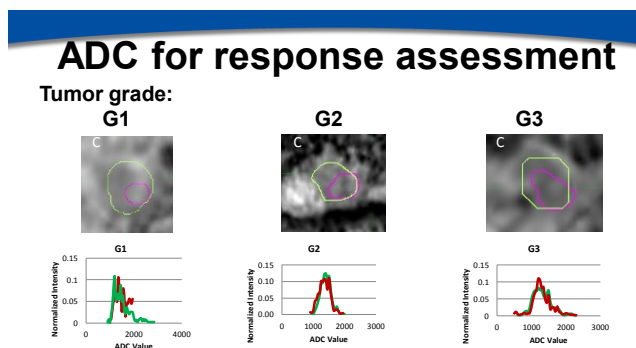
Model output

- Model output:
 - GTV (light blue)
 - FT (green),
 - NT (yellow),
- CT:
 - yellow initial GTV before treatment
 - red final GTV
 - Blue pancreas boarder.

Working in progress.....
MO-RPM-GePD-JT-4: e-poster

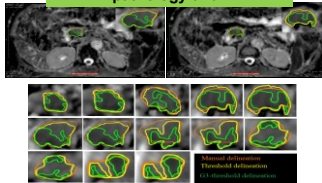






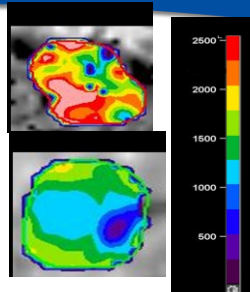
Quantitative ADC

link pathology and ADC



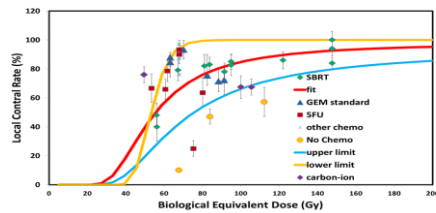
- Cut-off for G1/G2 = $1.68 \times 10^{-3} \text{ mm}^2/\text{s}$
- Cut-off for G3 = $1.47 \times 10^{-3} \text{ mm}^2/\text{s}$

Delineation of Spatially-Variied High-Risk GTV in Pancreatic Adenocarcinoma Using MRI-ADC Maps
Dalah & Li, et al. Int J Radiat Oncol Bio Phys 2014;90:S253



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Chemo-RT for locally advanced pancreatic cancer



Data:

- 1) SBRT+GEM (12 studies)
- 1) Conv RT+GEM (9)
- 2) Conv RT+5FU (11)
- 3) RT alone (3)
- 4) Carbon RT (3)

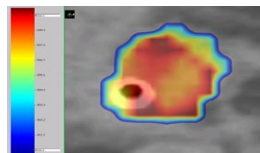
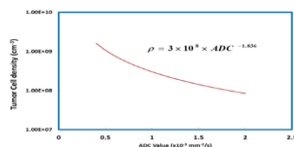
Local Control Rate (%)

Biological Equivalent Dose (Gy)

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ADC-based dose painting during ART for pancreatic cancer

Cell Line Name	Tumor Grade	ADC cutoff (mm^2/s)	α (Gy^{-2})	β (Gy^{-2})
Capan 2	G3	1.47×10^{-3}	0.24	0.018
Panc-1	G2/G3	1.68×10^{-3}	0.32	0.016



Dose prescription map

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Dose Escalation for Unresectable Pancreatic Cancer

- DPC4 gene status
- DEC/ADC defined GTV
- 4DCT/MRI planning

GTV: 31x2.25=69.75Gy
PTV: 33x1.76=54.56Gy

Duodenum-Excluded from boost
Dmax 63 Gy
V55< 1cc

PI: Beth Erickson
8 patients enrolled so far

MR-Linac

Initial Performance Tests of a High Field MR-Linac

Eric Paulson, Xinfeng Chen, Nikolai Mickevicius, Slade Klawikowski, Ergun Ahunbay, X. Allen Li

TU-FG-FS2-9
 Tuesday, 8/1, 1:45 PM
 Room: Four Seasons 2

MR-Linac Scenario

	Pre-Beam	Beam-On	Post-Beam
Imaging	MRI (3D, 4D)	Real-Time MRI (Cine, 3D)	
Planning	Adapt Re-plan		Accumulate Dose
Treatment		Radiation Delivery (gating, tracking)	

Summary

Quantitative imaging acquired during RT delivery can be potentially used for early assessment of RT response, thus, for adaptive RT.
