MOFFITT CANCER CENTER

Future of Quantitative Imaging Biomarkers (Radiomics) in Radiotherapy and Immunotherapy

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Division of Quantitative Science
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July 14th, 2020

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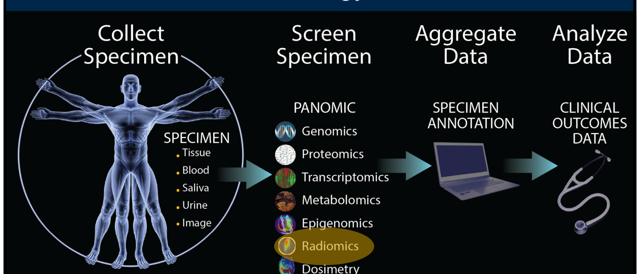
The *Pan*-Omics of Oncology



RADIATION ONCOLOGY | El Naqa et al, PMB, 2017 | MICHIGAN MEDICINE

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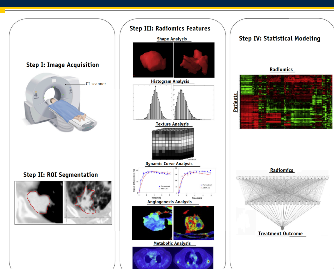
Radiomics

A 'new' form of –omics
- Quantitative information from multi-imaging modalities (PET, CT, MRI, etc) could be related to biological and clinical endpoints
- In oncology, *it is decoding the Tumor Phenotype with Non-Invasive Imaging* (Lambin, 2012)



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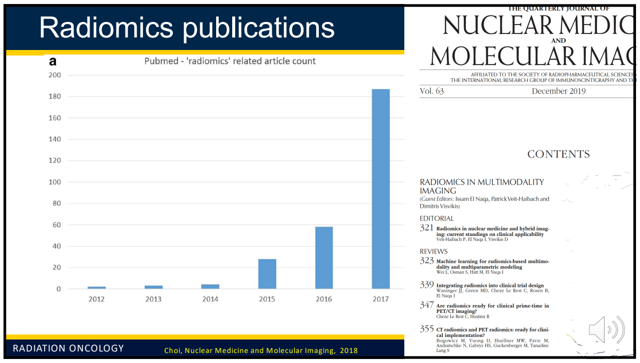
Radiomics publications
a
Pubmed - 'radiomics' related article count
200
180
160
140
120
100
80
60
40
20
0
2012
2013
2014
2015
2016
2017
NUCLEAR MEDIC
AND
MOLECULAR IMAG
Vol. 63
December 2019
CONTENTS
RADIOMICS IN MULTIMODALITY IMAGING
EDITORIAL
REVIEWS
RADIATION ONCOLOGY
Choi, Nuclear Medicine and Molecular Imaging, 2018

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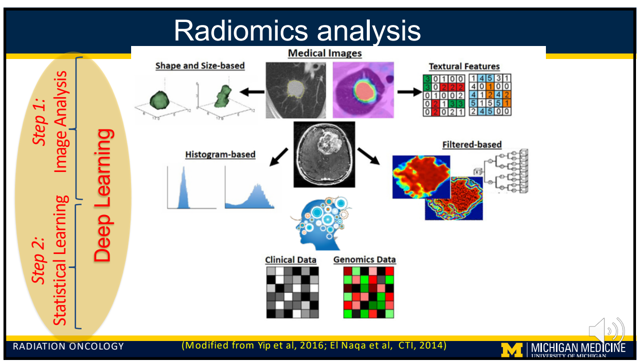
Radiomics analysis
Step 1: Image Analysis
Step 2: Statistical Learning
Deep Learning
Shape and Size-based
Medical Images
Textural Features
Histogram-based
Filtered-based
Clinical Data
Genomics Data
RADIATION ONCOLOGY
(Modified from Yip et al, 2016; El Naqa et al, CTI, 2014)
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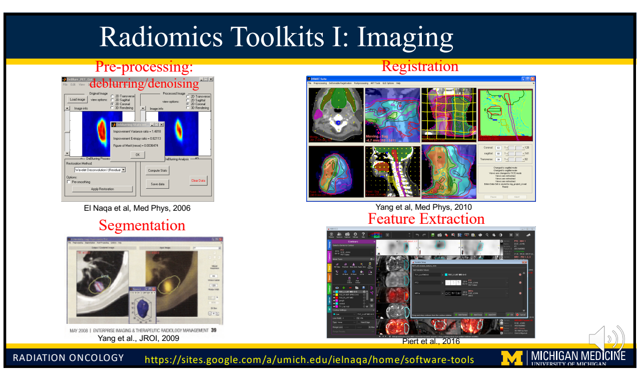
Radiomics Toolkits I: Imaging
Pre-processing: deblurring/denoising
Registration
El Naqa et al, Med Phys, 2006
Yang et al, Med Phys, 2010
Segmentation
Feature Extraction
Yang et al., JROI, 2009
Piert et al., 2016
RADIATION ONCOLOGY
https://sites.google.com/a/umich.edu/ielnaqa/home/software-tools
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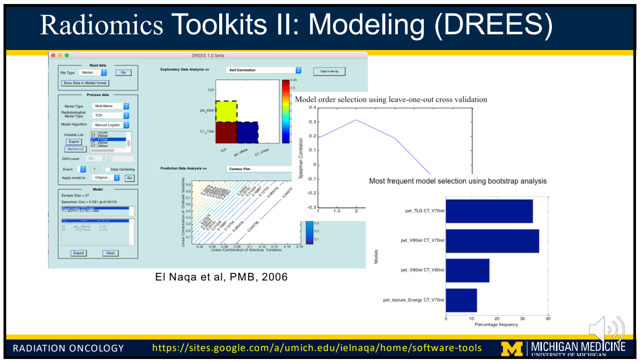
Radiomics Toolkits II: Modeling (DREES)
Model order selection using leave-one-out cross validation
Most frequent model selection using bootstrap analysis
El Naqa et al, PMB, 2006
RADIATION ONCOLOGY
https://sites.google.com/a/umich.edu/ielnaqa/home/software-tools
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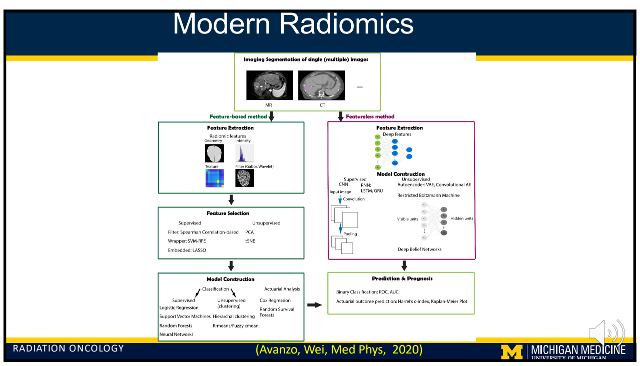
Modern Radiomics
Imaging Segmentation of single (multiple) images
Feature-based method
Featureless method
Feature Extraction
Feature Selection
Model Construction
Prediction & Prognosis
RADIATION ONCOLOGY
(Avanzo, Wei, Med Phys, 2020)
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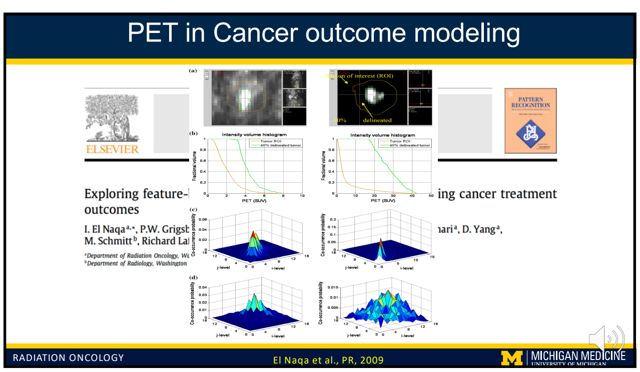
PET in Cancer outcome modeling
ELSEVIER
Exploring feature-
ing cancer treatment
outcomes
Intensity volume histogram
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El Naqa et al., PR, 2009
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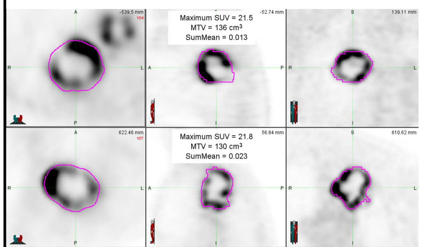
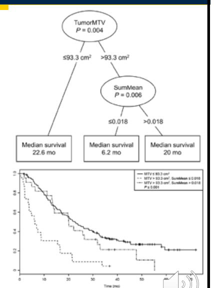
PET+Clinical in ACRIN 6668/RTOG 0235 in lung cancer outcome modeling





RADIATION ONCOLOGY Ohri et al, JNM, 2016 MICHIGAN MEDICINE

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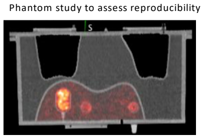
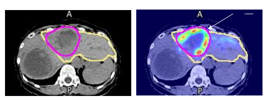
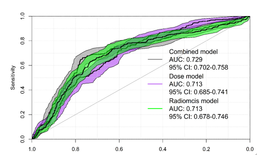
Y-90 PET radiomics for liver radioembolization prediction

Phantom study to assess reproducibility







Concordance Correlation Coefficient analysis of some select features

	Variance	Correlation	GLV	ZP	Strength
1 iteration vs. 2 iterations	0.96	0.99	0.93	0.94	0.98
Post smoothing vs. no smoothing	0.59	0.94	0.77	0.91	0.97
Scan 1 vs. Scan 2	0.22	0.88	0.87	0.93	0.93

RADIATION ONCOLOGY Wei, Dewaraja, et al, EANM, 2018 MICHIGAN MEDICINE

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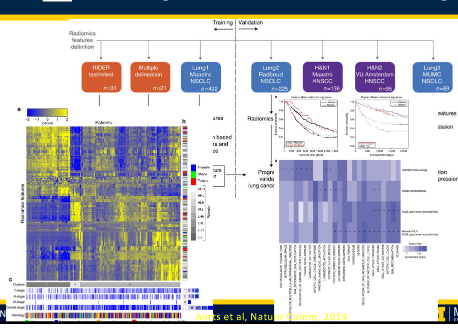
CT in in lung cancer outcome modeling



RADIATION ONCOLOGY Aerts et al, Nature Comm, 2014 MICHIGAN MEDICINE

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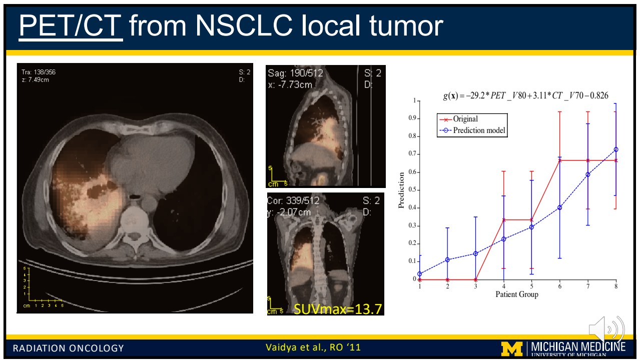

PET/CT from NSCLC local tumor
Sag: 190/512
x: -7.73cm
Cor: 339/512
y: -2.07cm
SUVmax=13.7
$g(x) = -29.2 * PET\_V80 + 3.11 * CT\_V70 - 0.826$
Original
Prediction model
Prediction
Patient Group
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Vaidya et al., RO '11
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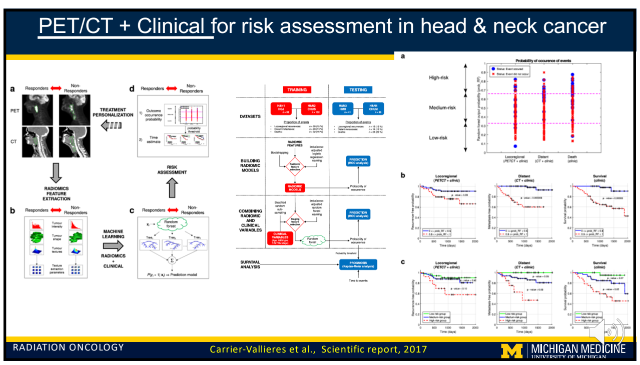

PET/CT + Clinical for risk assessment in head & neck cancer
TRAINING
TESTING
DATASETS
High-risk
Medium-risk
Low-risk
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Carrier-Vallieres et al., Scientific report, 2017
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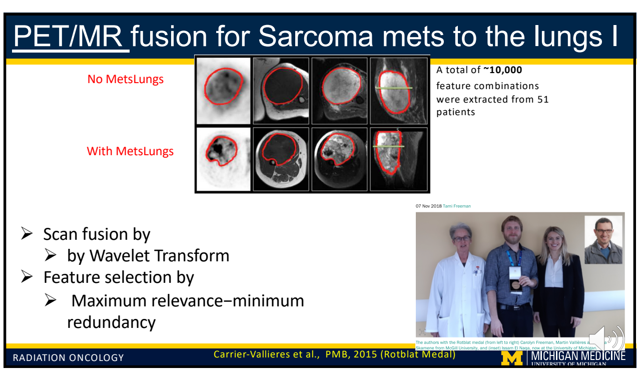

PET/MR fusion for Sarcoma mets to the lungs I
No MetsLungs
With MetsLungs
A total of ~10,000 feature combinations were extracted from 51 patients
Scan fusion by
by Wavelet Transform
Feature selection by
Maximum relevance–minimum redundancy
RADIATION ONCOLOGY
Carrier-Vallieres et al., PMB, 2015 (Rotblat Medal)
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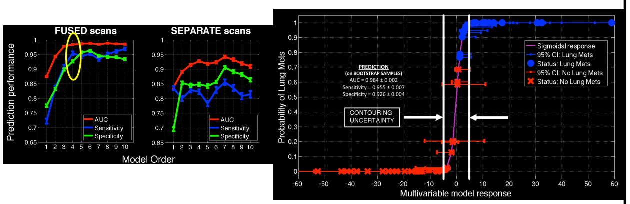
PET/MR fusion for Sarcoma mets to the lungs II



RADIATION ONCOLOGY Carrier-Vallieres et al., PMB, 2015 (Rotblat Medal) MICHIGAN MEDICINE

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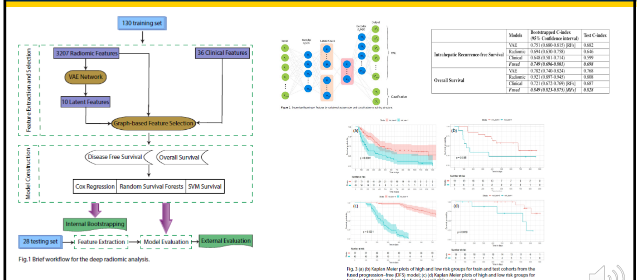
Prediction of Early Intrahepatic Progression Risk using Deep learning + Conventional radiomics I



RADIATION ONCOLOGY Wei et al., under review, 2020 MICHIGAN MEDICINE

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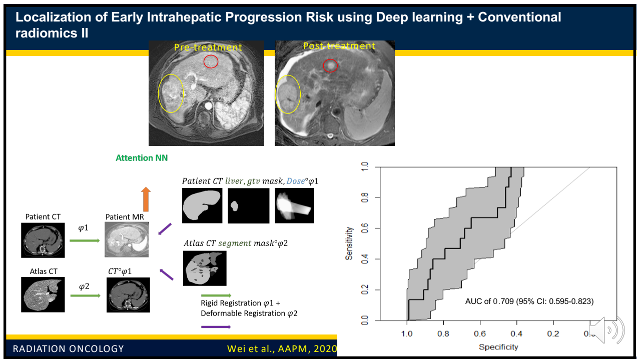
Localization of Early Intrahepatic Progression Risk using Deep learning + Conventional radiomics II



RADIATION ONCOLOGY Wei et al., AAPM, 2020

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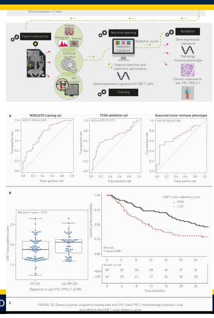
Radiomics for immunotherapy



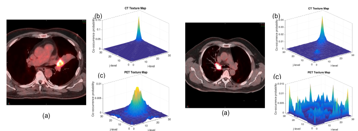


Figure 2. Responder case. (a) Pre-treatment fused PET/CT. (b) CT texture map (Heterogeneity index= 0.46). (c) PET texture (Heterogeneity index =0.68).

Figure 3. Non-Responder case. (a) Pre-treatment fused PET/CT. (b) CT texture map (Heterogeneity index= 0.58). (c) PET texture (Heterogeneity index = 0.82).

Sun et al., Lancet, 2018; El Naqa, editorial

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Conclusions

- Radiomics offers new opportunities to develop better understanding of oncology processes and for personalizing therapy
- Complementary information from hybrid (multi-modality) imaging (fused/separate) can enrich radiomics models and improve prediction power
- Machine/deep learning techniques can improve feature selection and statistical learning in radiomics analytics and modeling outcomes
- Proper integration of radiomics with clinical and other –omics (panomics) is necessary towards development of informed clinical decision support systems
- Main challenges for radiomics with machine learning methods
  - Harmonization and optimization of image acquisition methods
  - Validation and evaluation across independent datasets
  - Better interpretation of radiomics models is still lagging

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- Martin Vallieres, PhD
- *Lise Wei, PhD*
- Wei Zhang, PhD

THANK YOU!

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