Radiomics: methods and general applications

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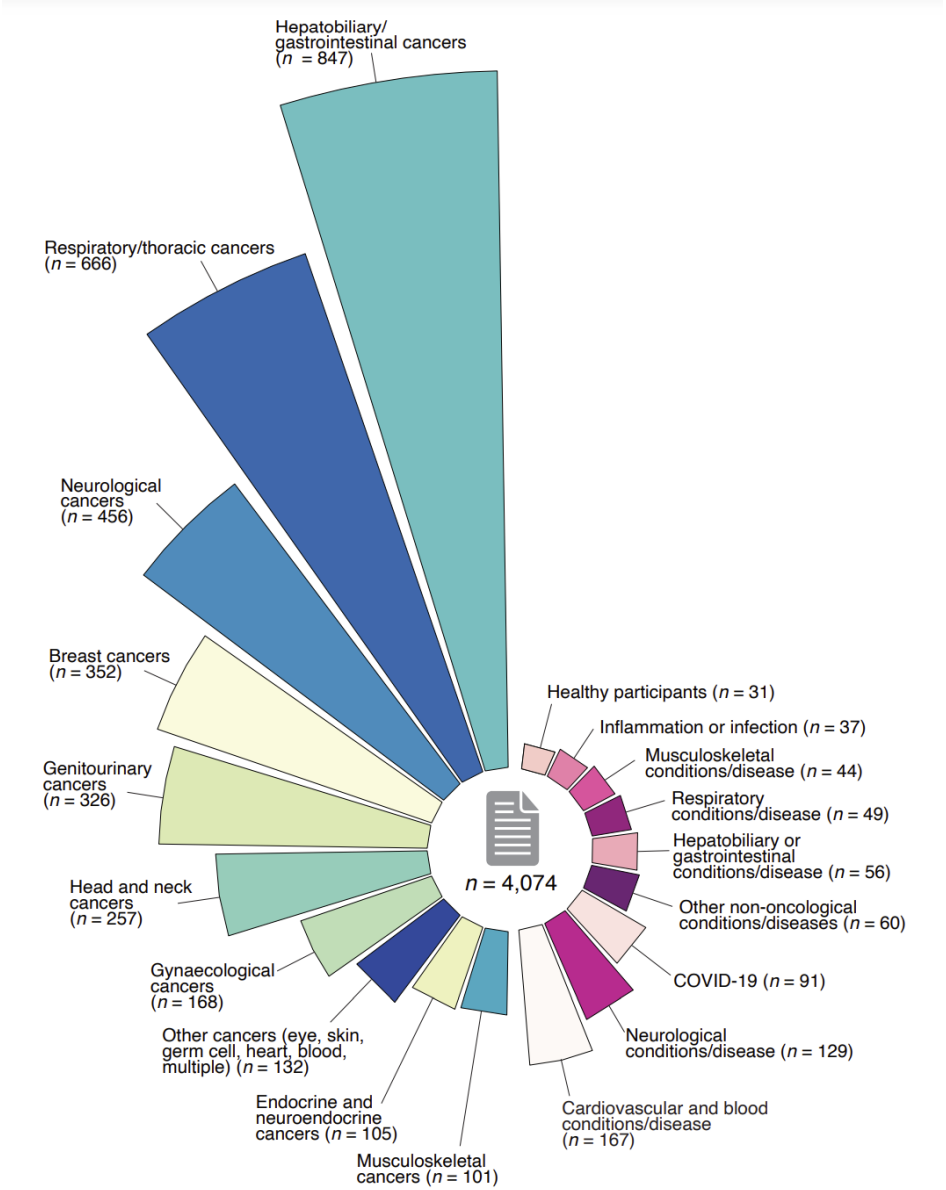
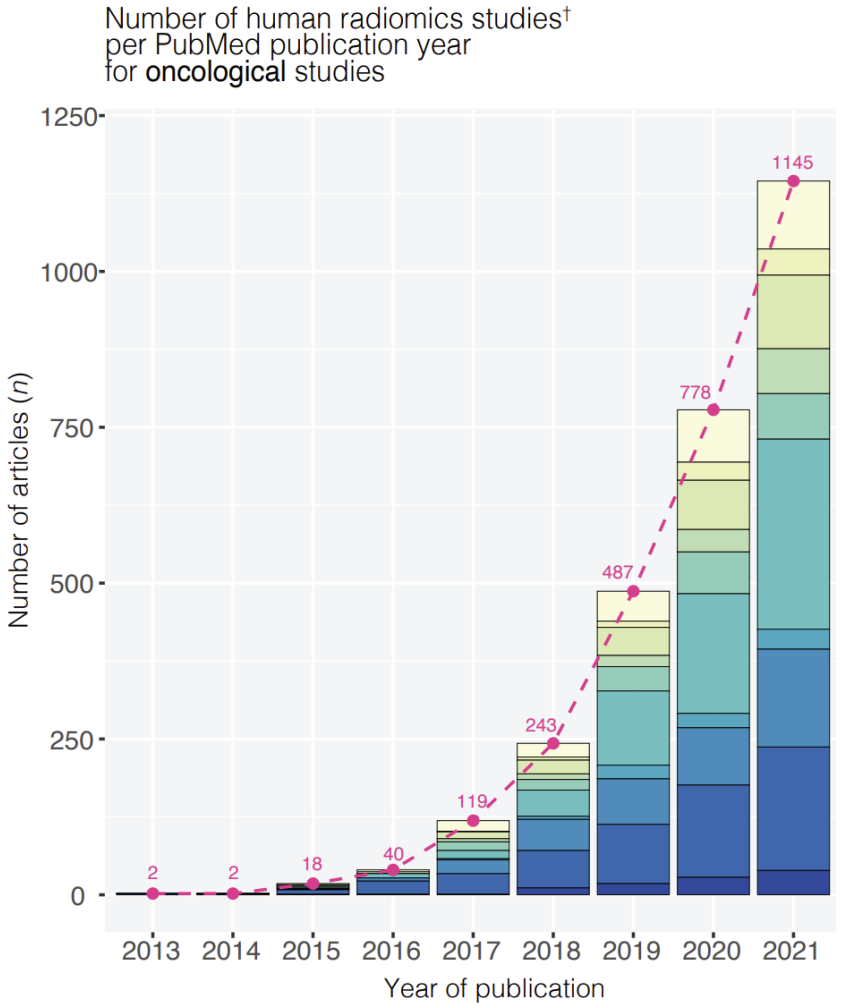
Disclosures

- Co-founder and shareholder, Lucida Medical
- Research support, GEHC, Canon
- Speakers' bureau, GEHC, Canon

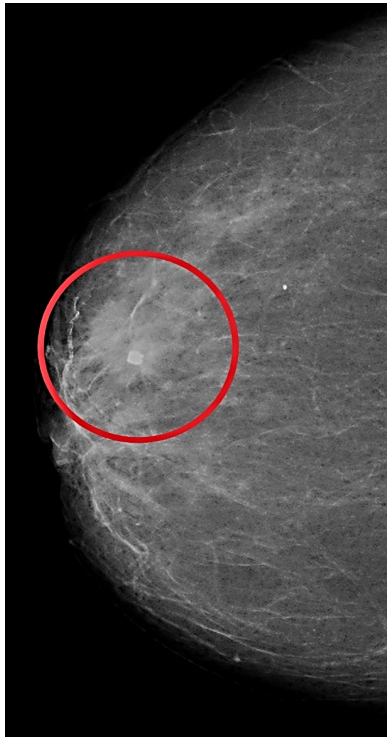
Radiomics Research

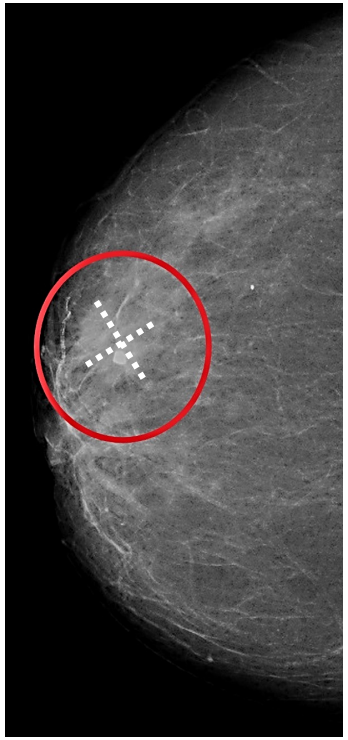


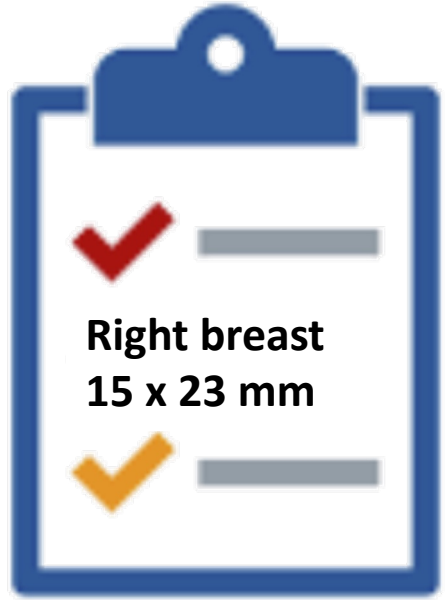


McCague C … Sala E, Woitek R 2022 Clin Rad

What does a radiologist do?





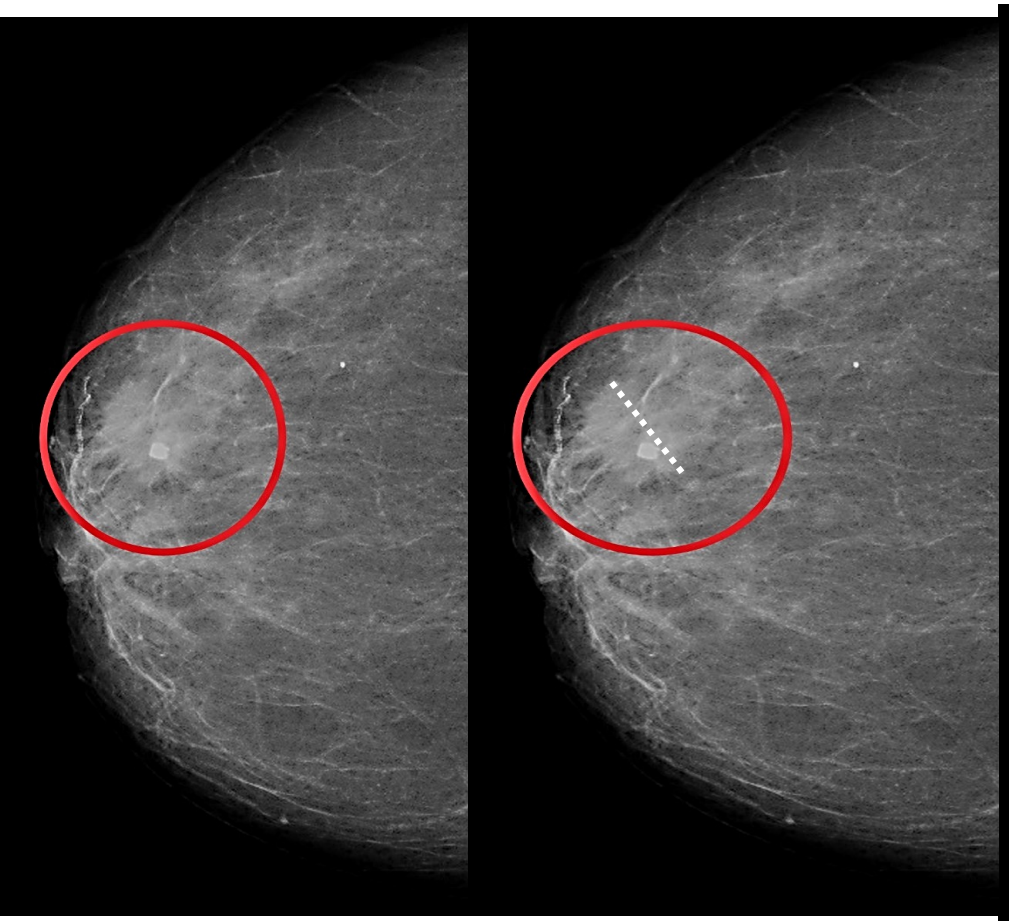


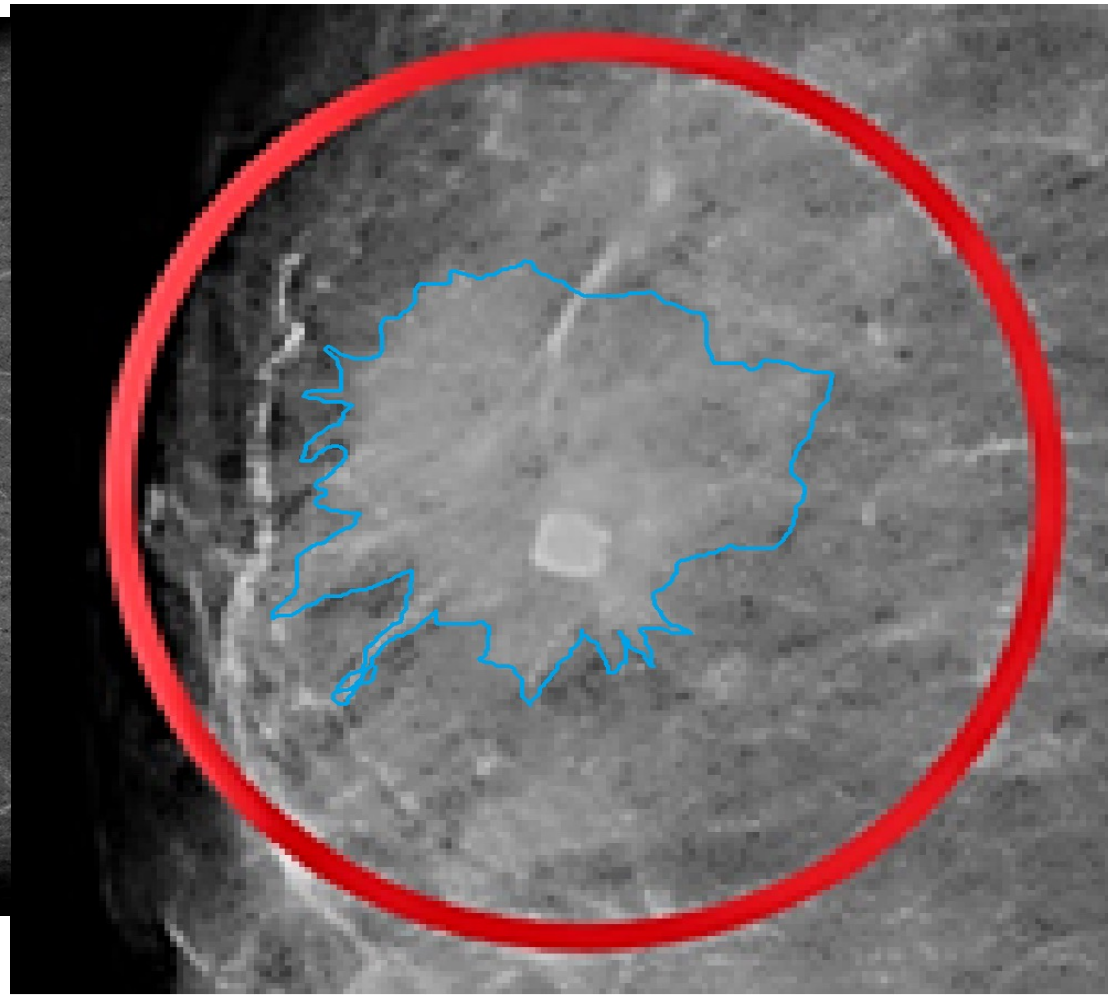
Detect **Measure** **Report**

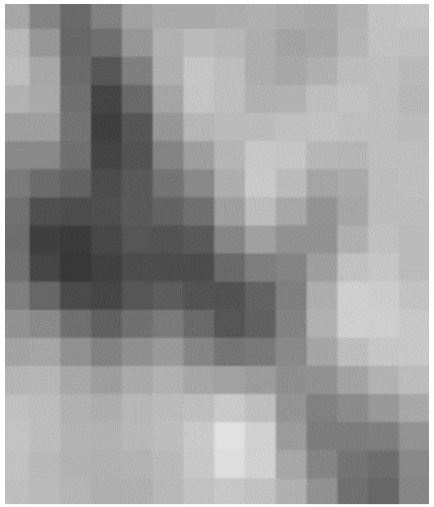
https://www.rcr.ac.uk/discover-and-explore/discover-radiology/what-does-clinical-radiologist-do

Do we capture all the information available on images?

Mammography

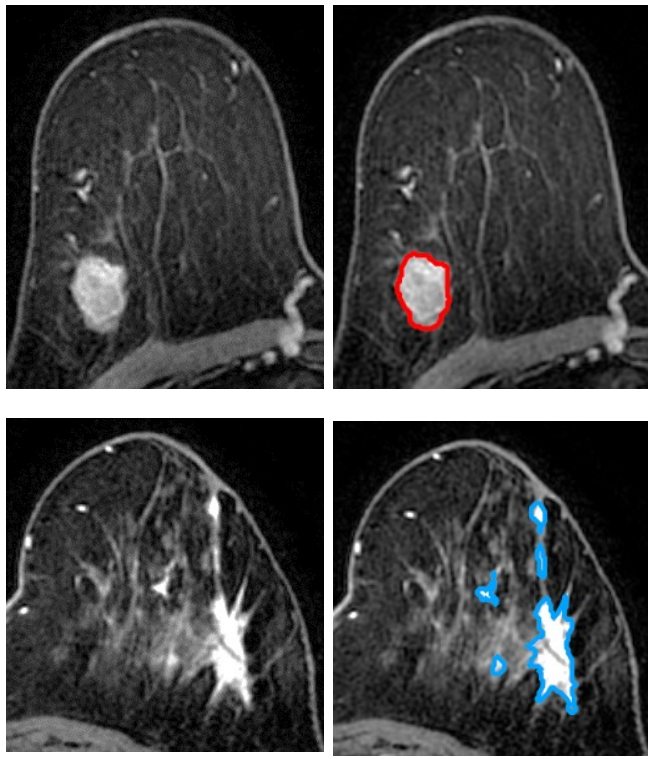






Radiomics - Quantitative Features

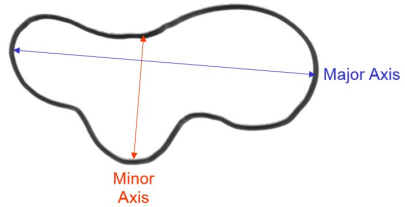
Imaging - Radiomics



Quantitative shape features

Volume

Diameter along different axes



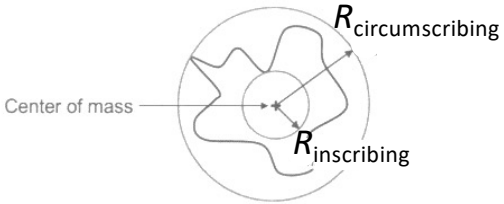
Maximum surface

Tumour compactness
area vs perimeter

compactness=0.764 compactness=0.668

Sphericity

$$\text{sphericity} = \frac{R_{inscribing}}{R_{circumscribing}}$$



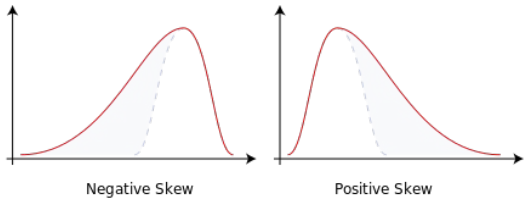
Wirth 2004 Shape Analysis & Measurement – Purdue University

Radiomics - Quantitative Features

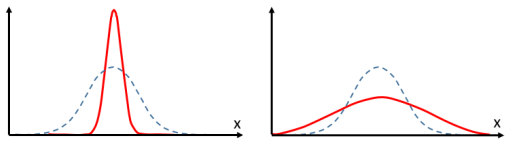
Imaging - Radiomics

Histogram analysis
1st order statistics

Skewness



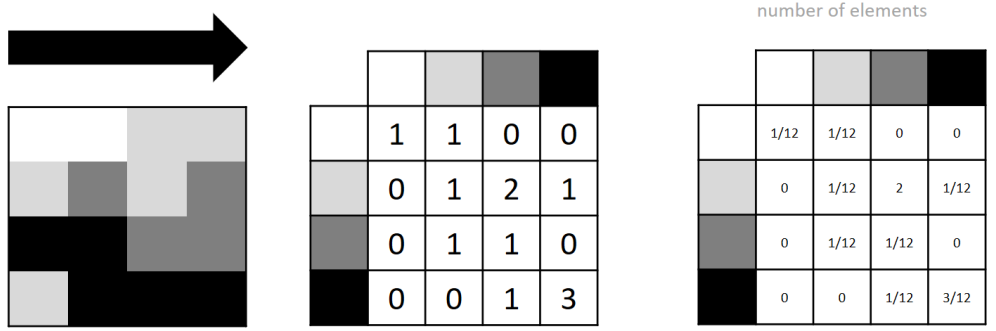
Kurtosis



etc …

2nd order statistics, **Texture** Analysis

GLCM
Grey level coocurrence matrix



Entropy	$-\sum_{i=0}^{n-1}\sum_{j=0}^{n-1} I(i,j)\log(I(i,j))$	Statistical measure of randomness related to the texture of an image.
Contrast	$\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}(i-j)(i-j)I(i,j)$	The intensity contrast between a pixel and its neighbors in a region of the image.
Correlation	$\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}\frac{(i-\mu_i)(j-\mu_j)I(i,j)}{\sigma_i\sigma_j}$	Measure of the linear dependency between the intensity values of pixels at particular positions relative to each other.
Energy	$\sum_{i=0}^{n-1}\sum_{j=0}^{n-1} I(i,j)I(i,j)$	The sum of the squared elements in the GLCM (gray-level co-occurrence matrix).
Homogeneity	$\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}\frac{I(i,j)}{1+\lvert i-j\rvert}$	Measure of the closeness of the distribution of the elements in the GLCM to the GLCM diagonal.

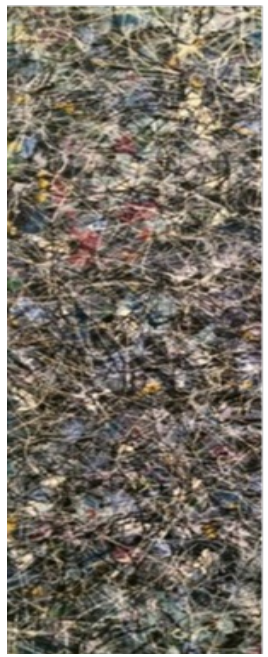
doi:10.1371/journal.pntd.0004356.t001

etc …

Examples of handcrafted features

A bit of (art) history

Homogeneity

0.54	0.54	0.76	0.79	0.85	0.89
					
7.84	7.69	7.09	7.37	6.82	5.82

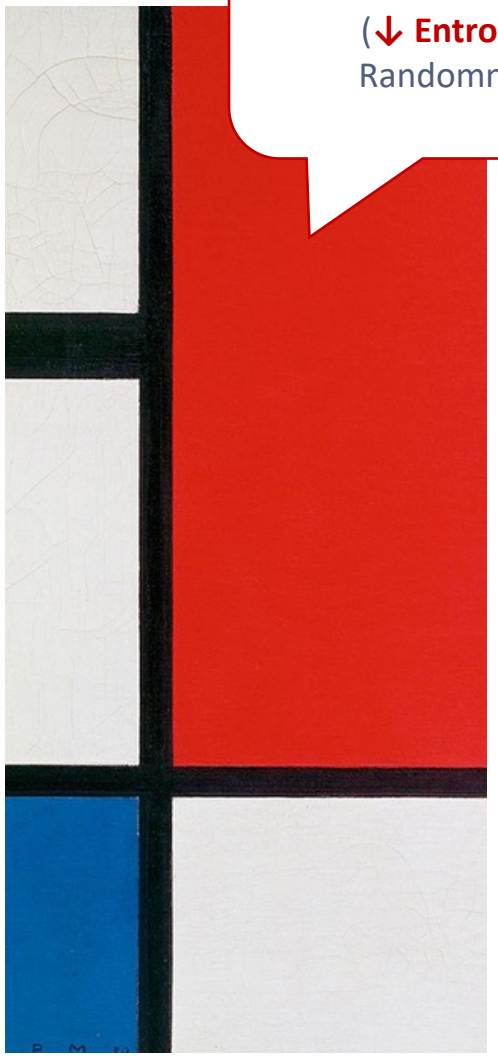
Entropy (Randomness)

a-e) Jackson Pollock

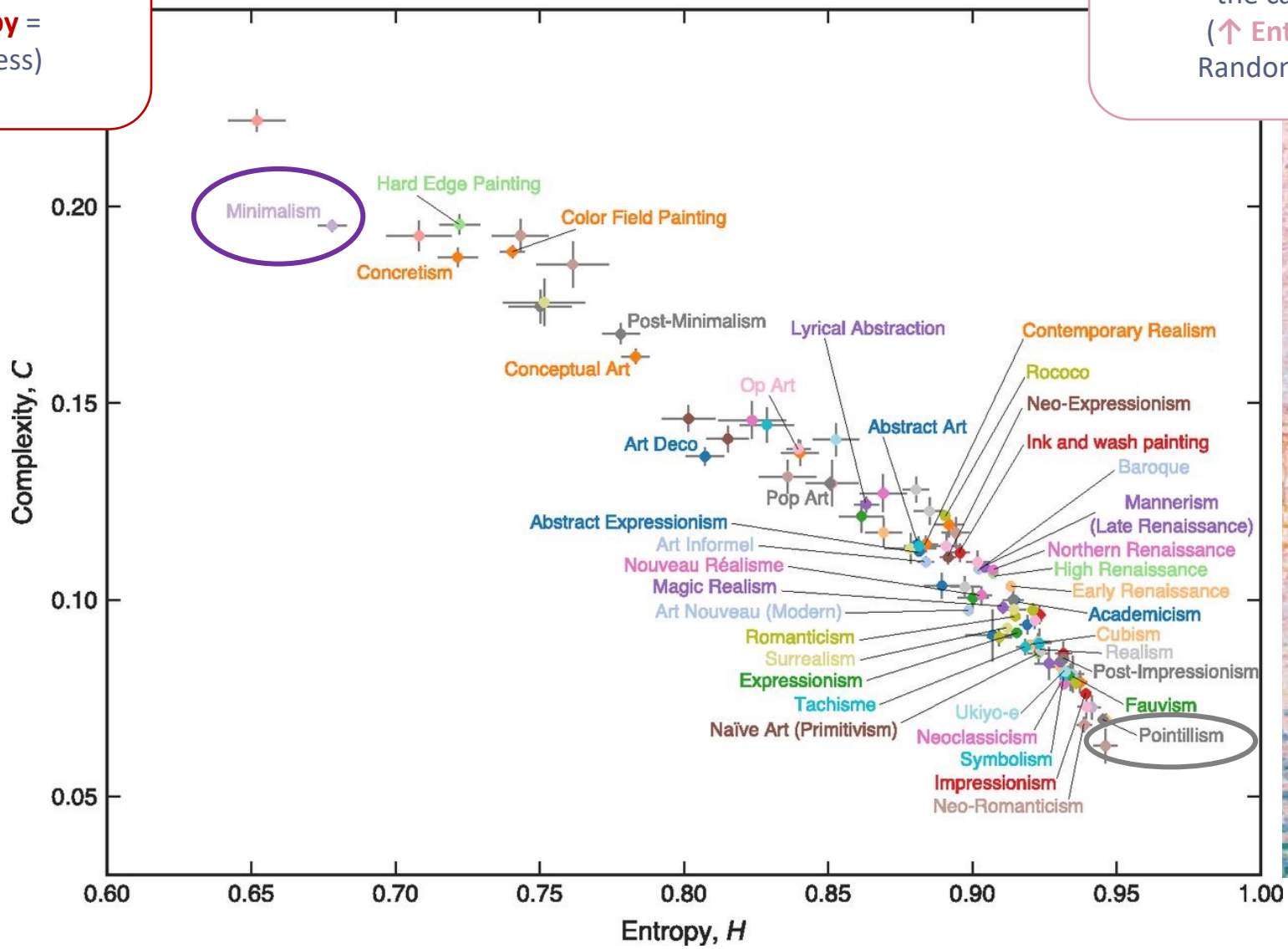
f) Mark Rothko

A bit of (art) history

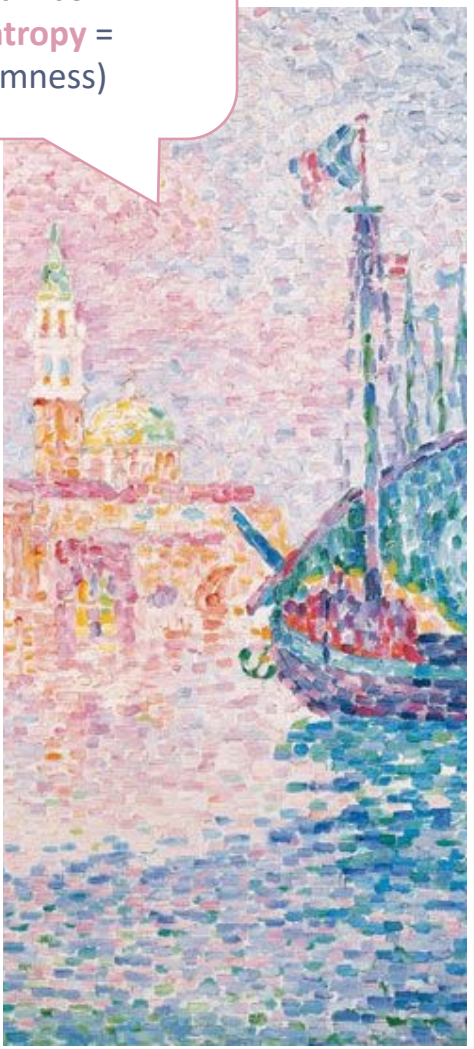
Red is only found within this rectangle (↓ **Entropy** = Randomness)



Piet Mondrian 1930



A pink dot can be found almost anywhere across the canvas (↑ **Entropy** = Randomness)



Paul Signac 1909

Sigaki et al. 2018 PNAS

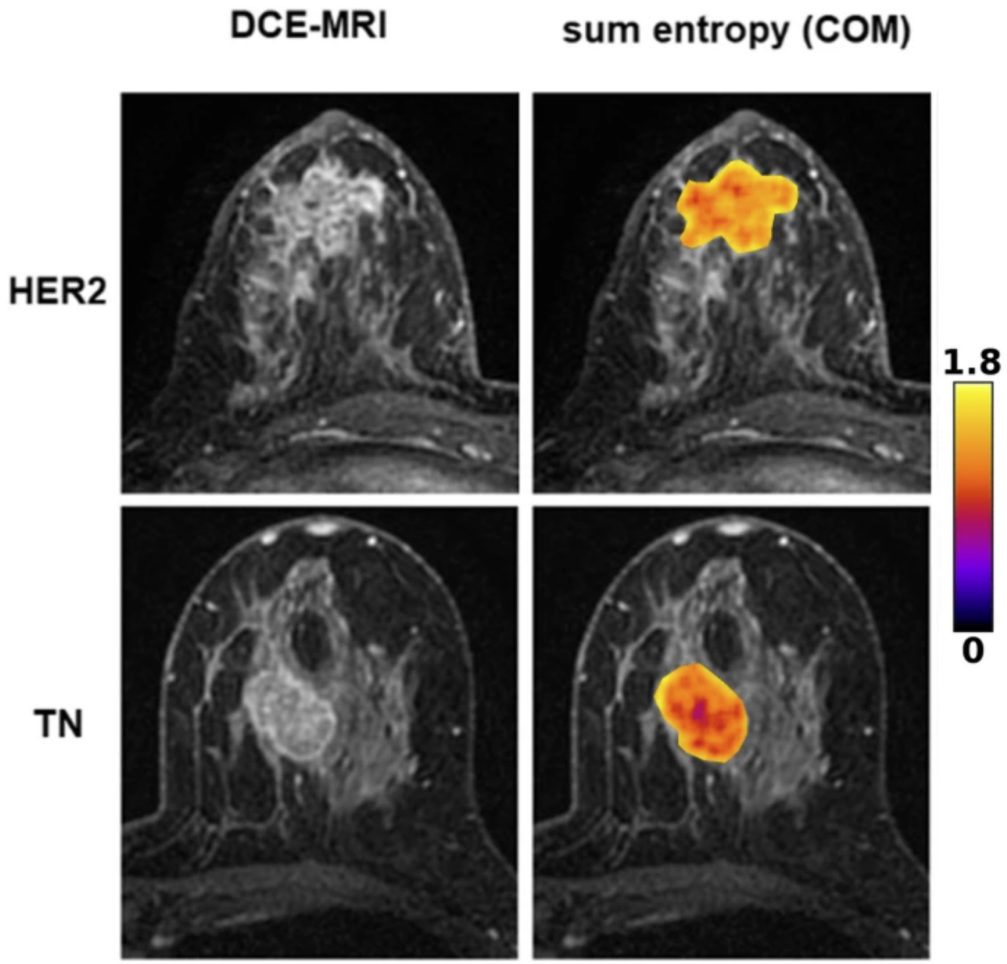
Entropy – "randomness" of pixels

Courtesy of Prof Ramona Woitek

Radiomics to distinguish between intrinsic subtypes

Luminal B cancers have distinct radiomic signatures:

- **luminal B vs. luminal A**, 84.2%
- luminal B vs. triple negative, 83.9%
- luminal B vs. all others, 89%

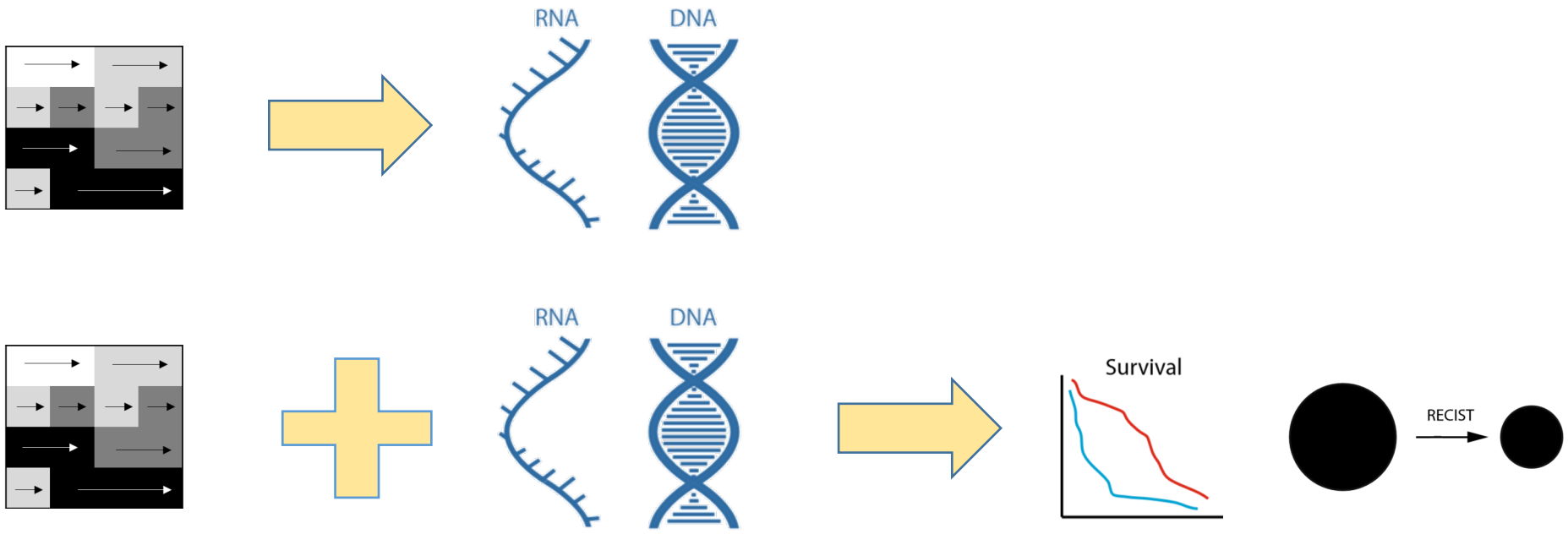


Leithner et al. Radiomic signatures with contrast-enhanced MRI … *Breast Cancer Res* 2019

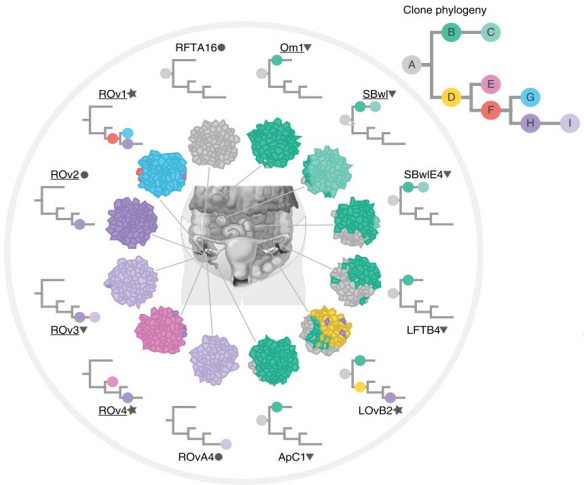
Radiogenomics

Understanding relationship between **radiomics** (imaging phenotype) and **genomics** (transcriptomics)

Importance of **heterogeneity in HGSOC**

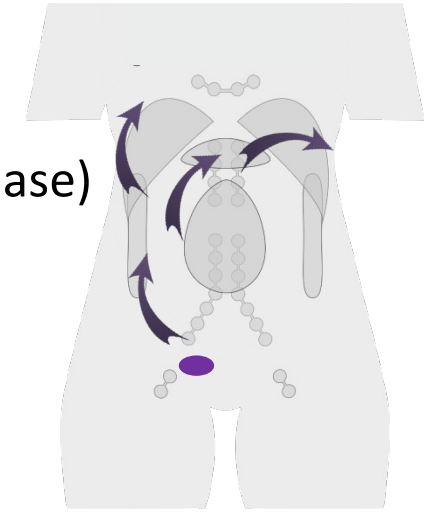


High Grade Serous Ovarian Cancer (HGSOC)



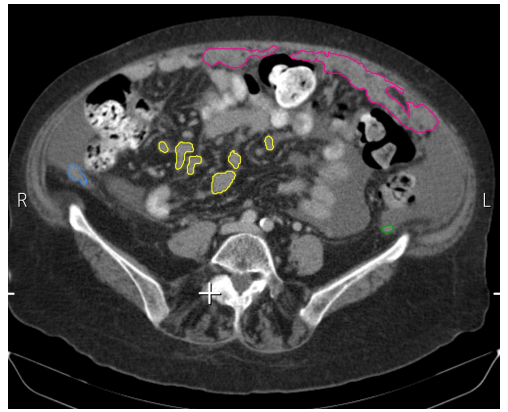
Highest mortality of all gynaecological malignancies

5-year overall survival rate: 20–40% FIGO III & 10-18% FIGO IV
~75% diagnosed at advanced stages (multi-site metastatic disease)



Genomic heterogeneity

Metastases in different sites harbor different **resistance mechanisms**



Neoadjuvant chemotherapy (NACT)
+ delayed primary surgery (DPS)

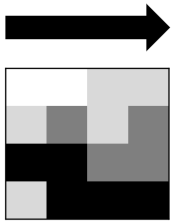
→ Can we predict response to NACT?

Vergote et al. NEJM 2010
Kehoe et al. Lancet 2015
Coward et al. Int J Womens Health 2015
McPherson et al. Nat Genet 2016

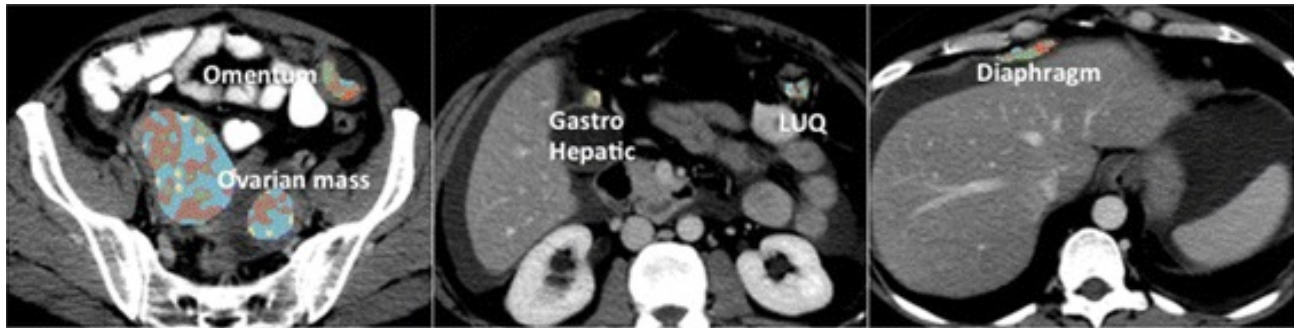
Nick et al. Nat Rev Clin Oncol 2015
Winter et al. JCO 2008
Nougaret Radiographics 2012

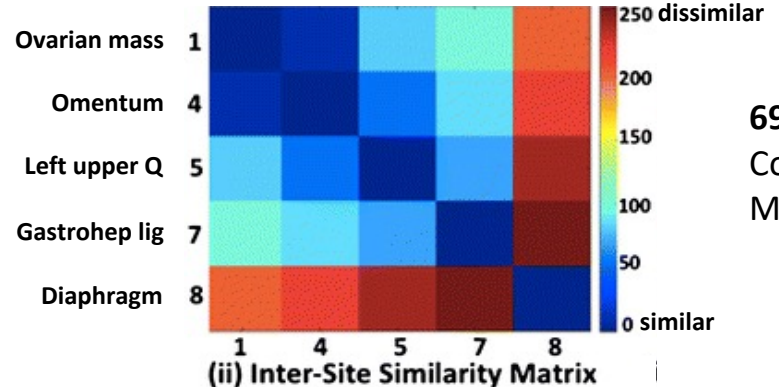
Inter-lesion Heterogeneity

GLCM
Grey level coocurrence matrix

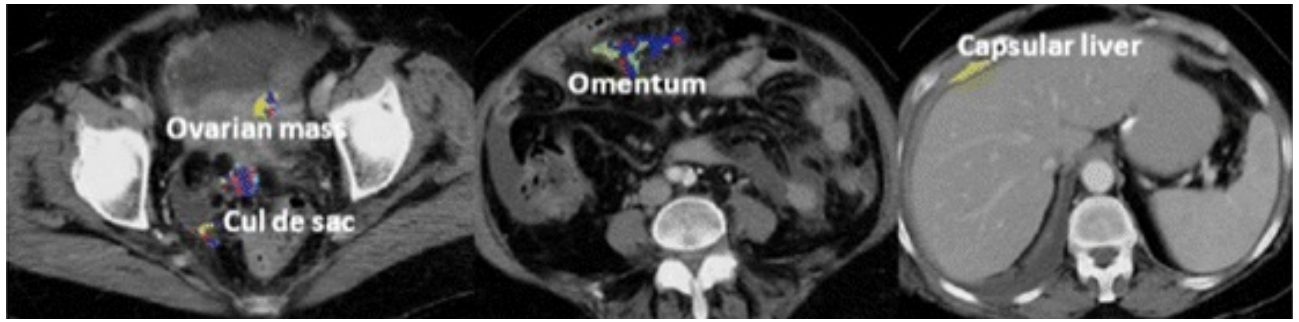


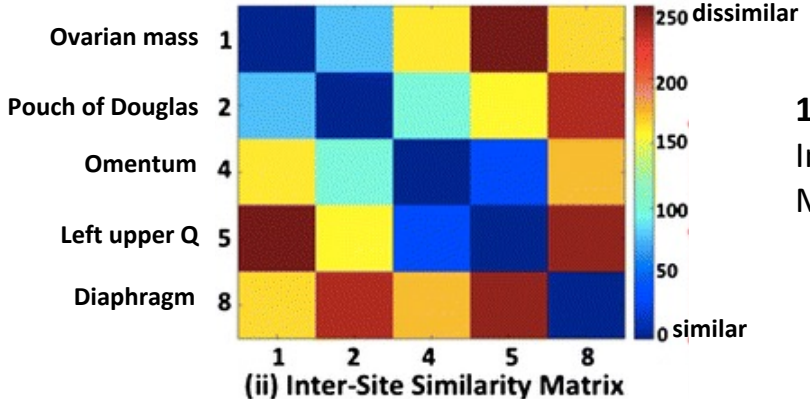
2nd order/ texture features computed for each voxel inside lesion
Pairwise similarities computed for all sites → Inter-Site Similarity Matrix





69 months OS
Complete resection
Mesenchymal subtype

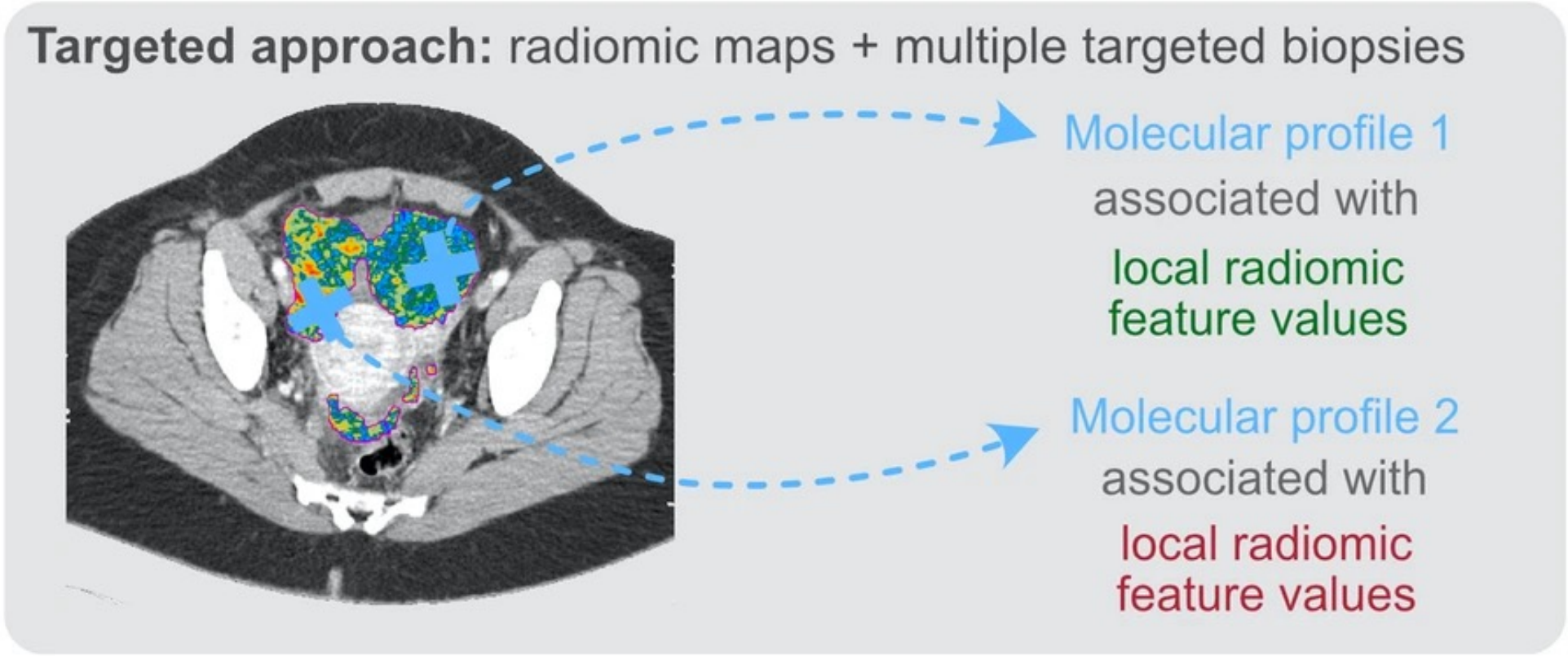




10 months OS
Incomplete resection
Mesenchymal subtype

Vargas et al. Eur Radiol 2017

Spatial Radiomics: Habitats

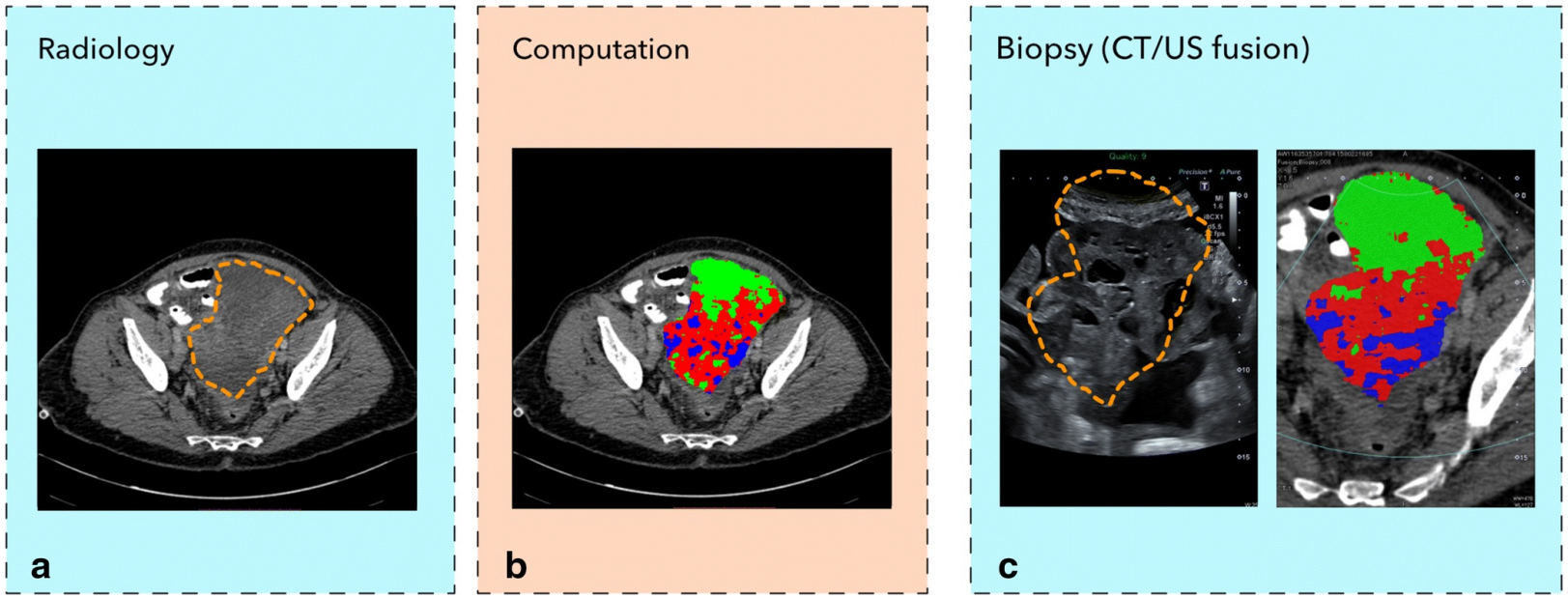


Radiomic-pathologic-molecular Correlation

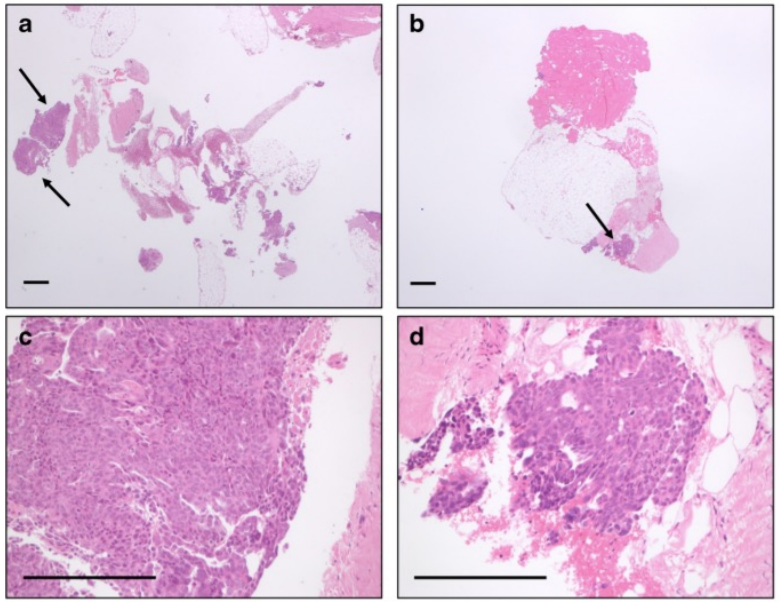
- Customised **3D-printed tumour moulds** for targeted tissue sampling
- **US-fusion biopsies** (overlay of radiomic habitats from CT during US-guided biopsies)

P. Martin-Gonzalez, MCO, et al., Insights into Imaging 2020

US-fusion biopsies



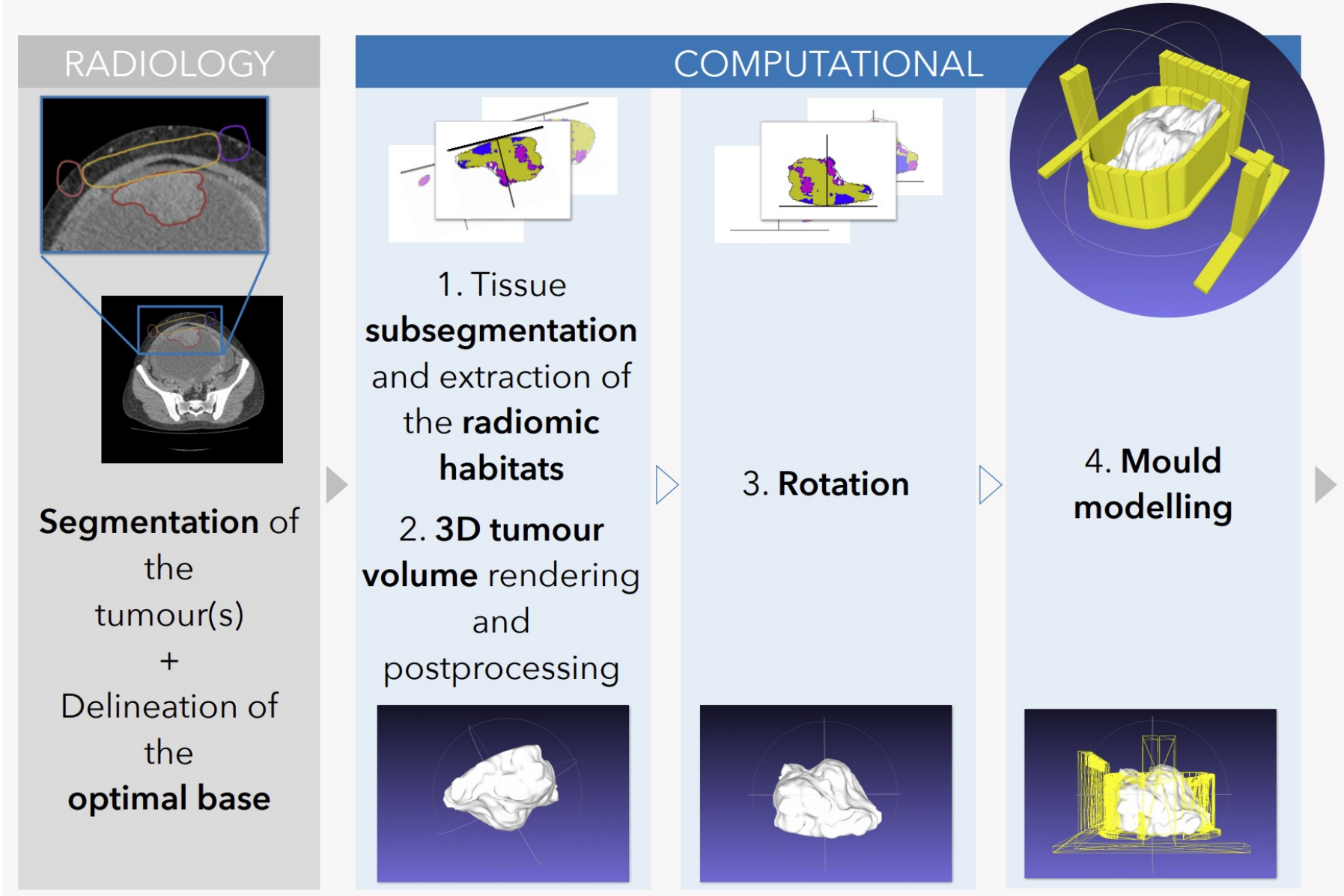
Targeted tissue characterisation



Beer L et al. Eur Radiol 2020

Work in collaboration with Canon Medical Systems

3D-printed tumour moulds

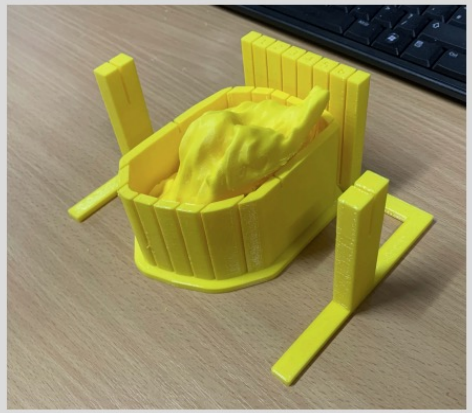


Delgado-Ortet et al. 26th Medical Imaging Understanding and Analysis (MIUA) Conference 2022

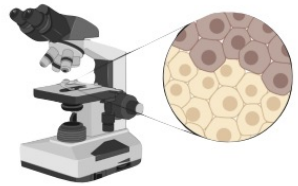
3D-printed tumour moulds

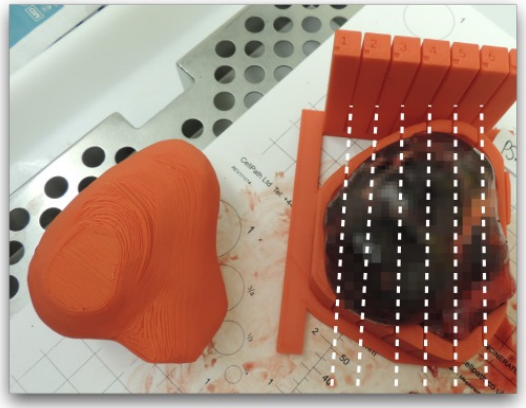
SURGERY

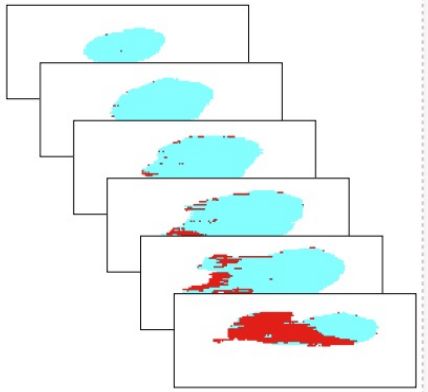
PATHOLOGY

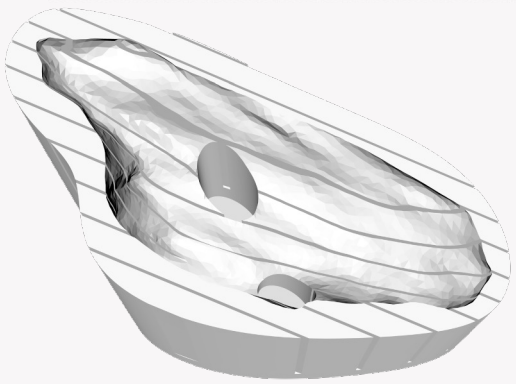


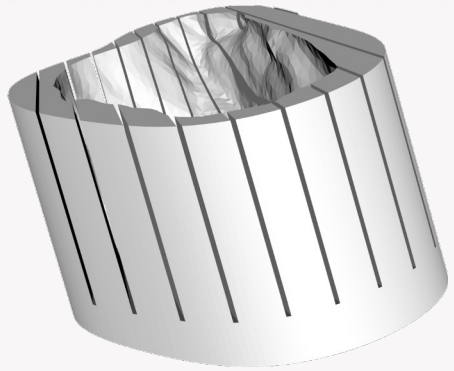
The **3D-printed mould and tumour** are brought to surgery and pathology **to aid the tissue sampling based on the radiomic habitats**





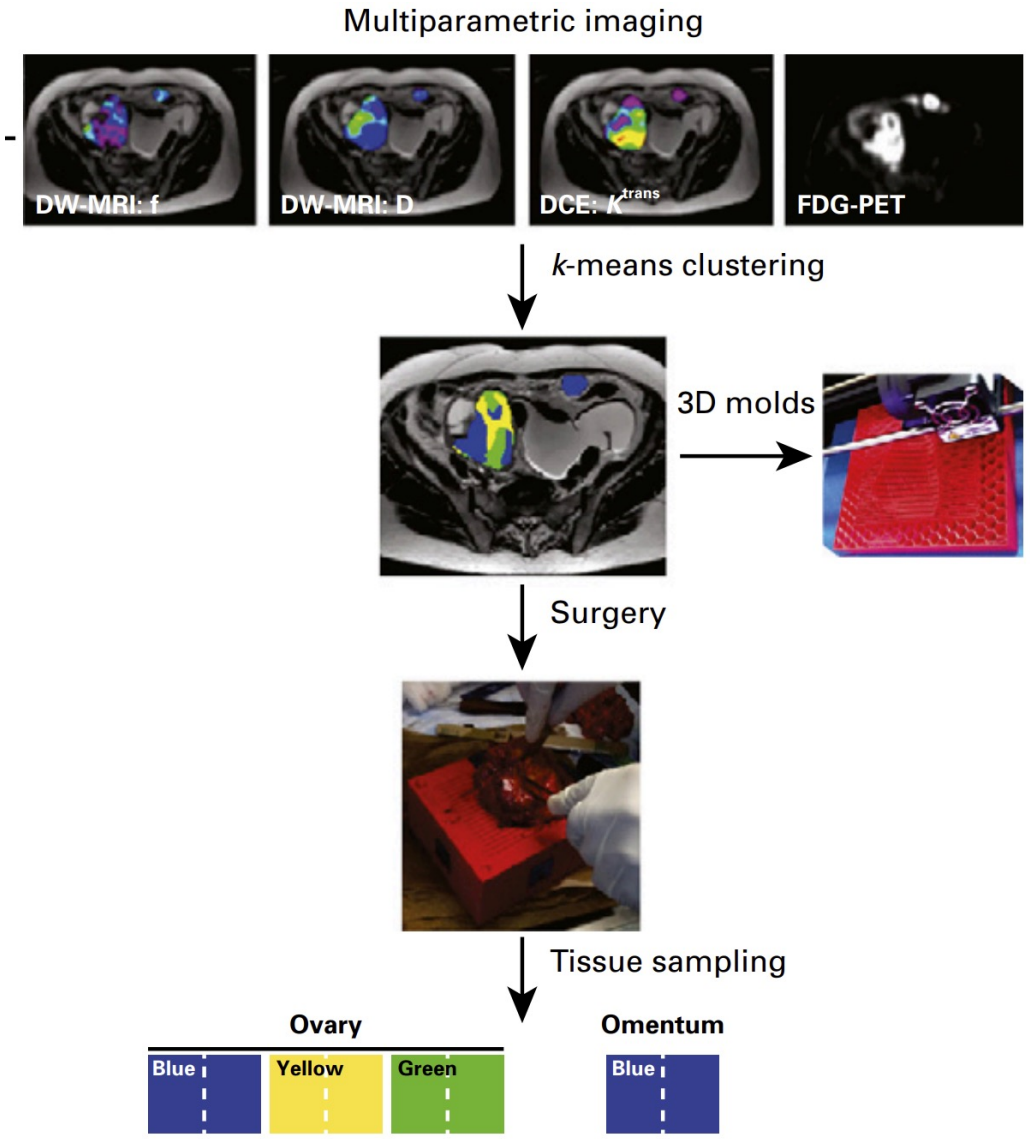


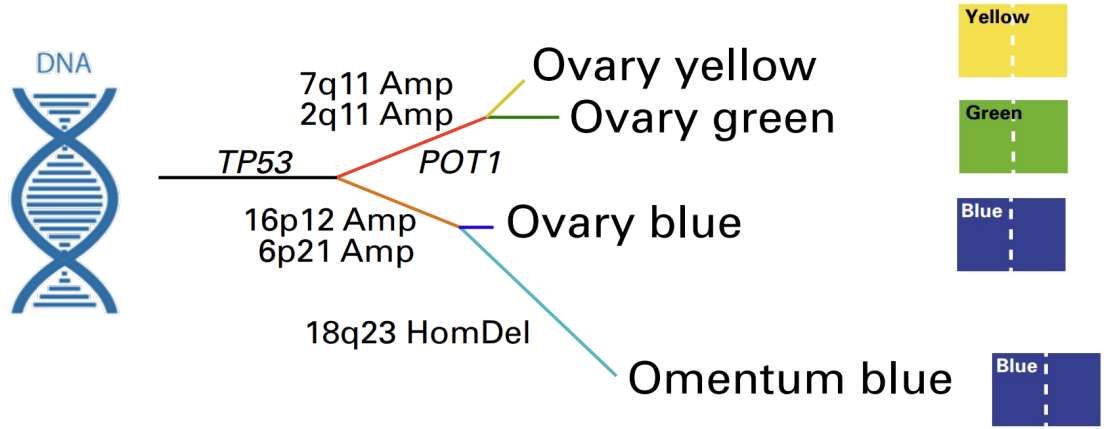


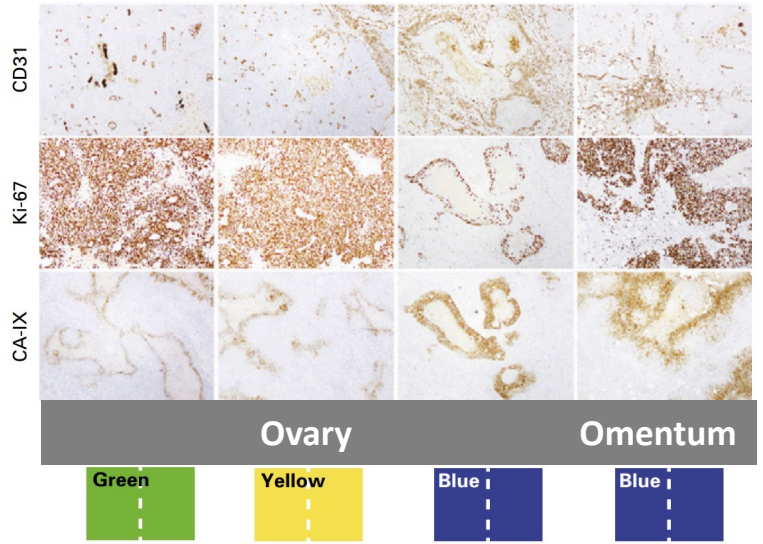


Delgado-Ortet et al. 26th Medical Imaging Understanding and Analysis (MIUA) Conference 2022

3D-printed tumour moulds







Weigelt et al. 2019 JCO Precision Oncology

Radiogenomic response predictor for HGSOC

Patient cohort (n=138)

n=92 eligible patients

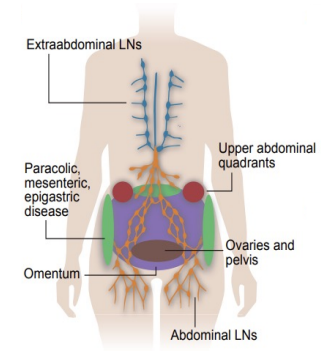
n=46 External validation

n=72 Training

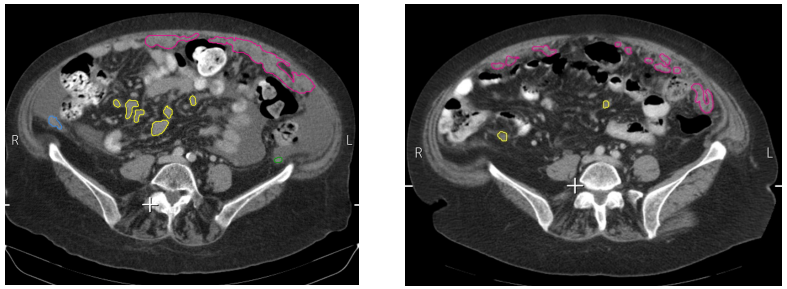
n=20 Hold-out validation

Predict response
to neoadjuvant chemotherapy (NACT)
[change in tumour volume]
from baseline scans

Manual segmentations
of whole tumour burden



CT scans



Pre-NACT

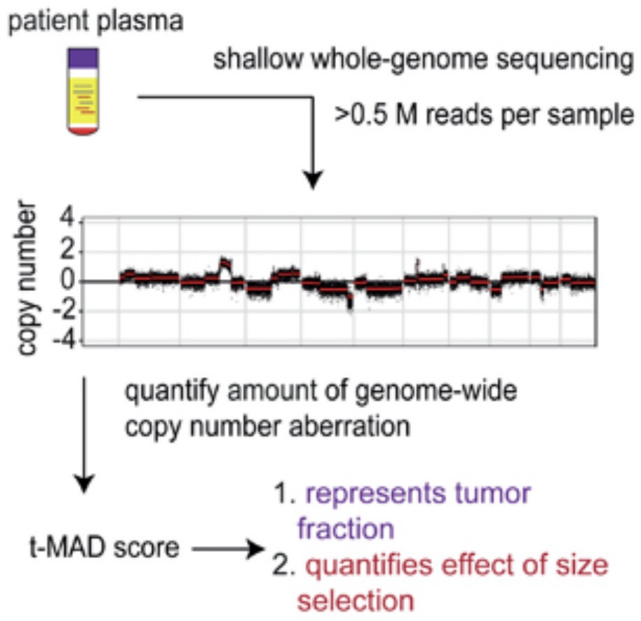
Post-NACT

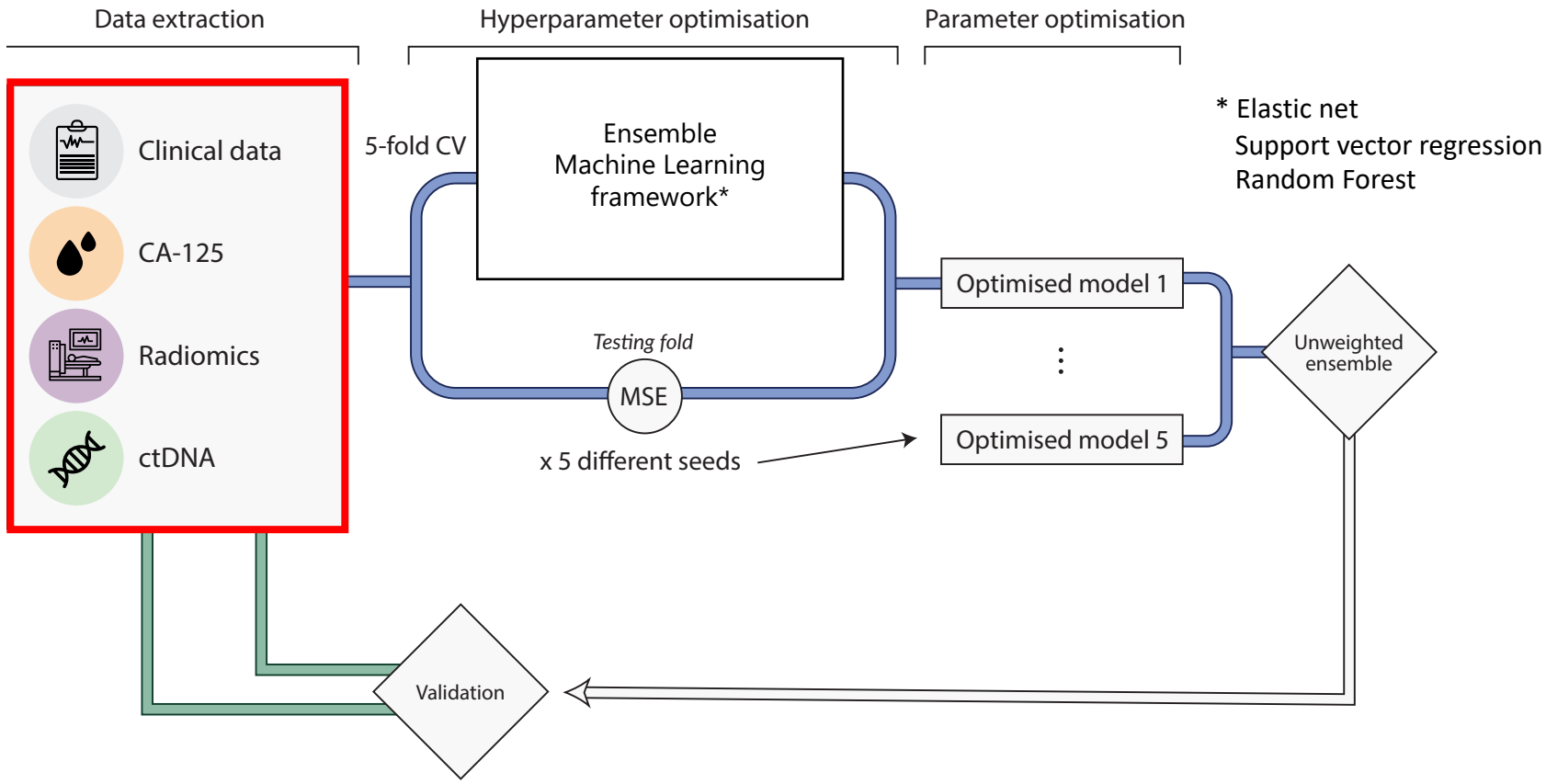
Crispin-Ortuzar M & Woitek R et al. under review *Nat Comms*

Radiogenomic response predictor for HGSOC

tMAD
trimmed Median Absolute Deviation from copy-number neutrality

sWGS
Quantification of **genome wide copy number aberrations**

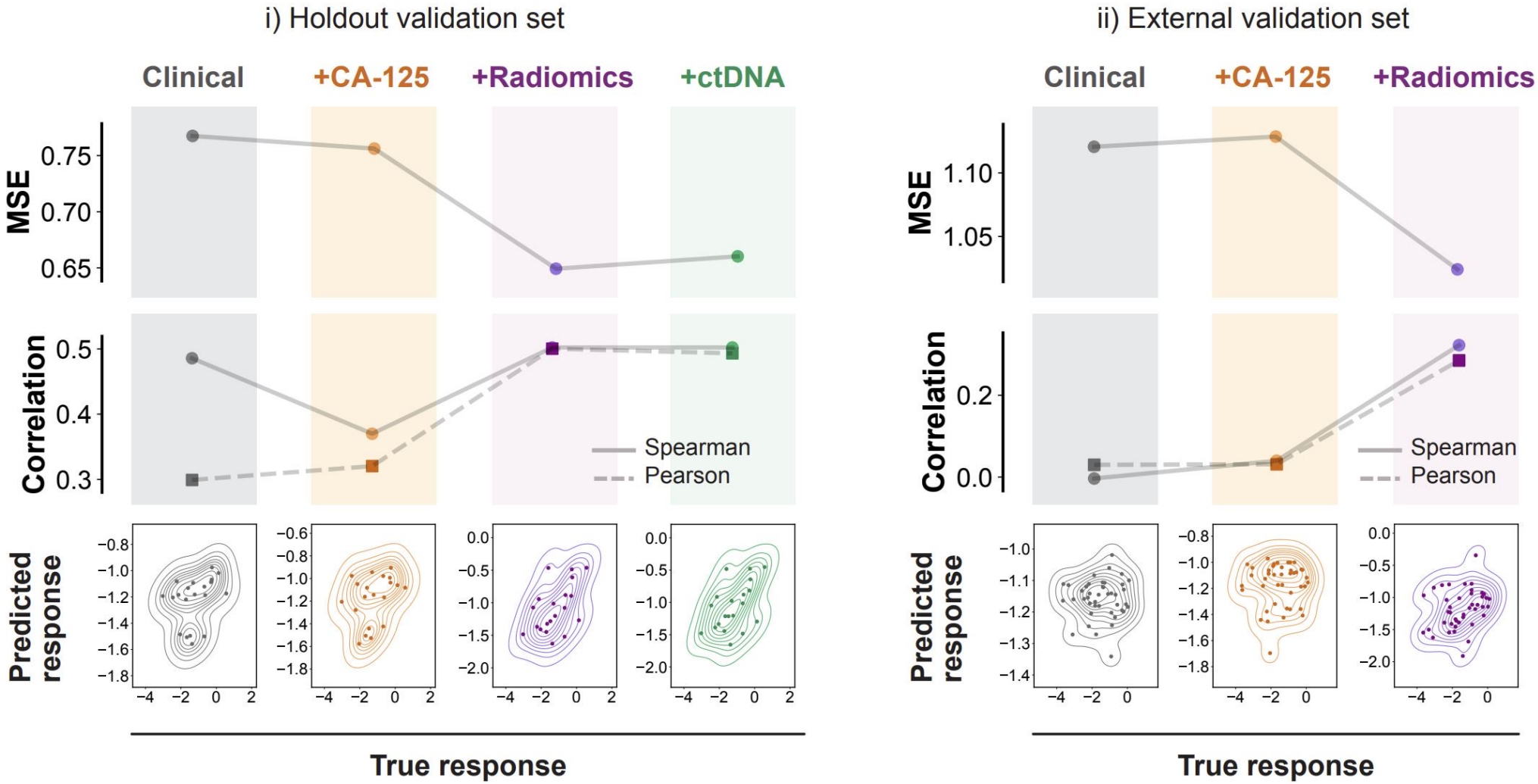




Crispin-Ortuzar M & Woitek R et al. under review *Nat Comms*

Data integration improves response prediction

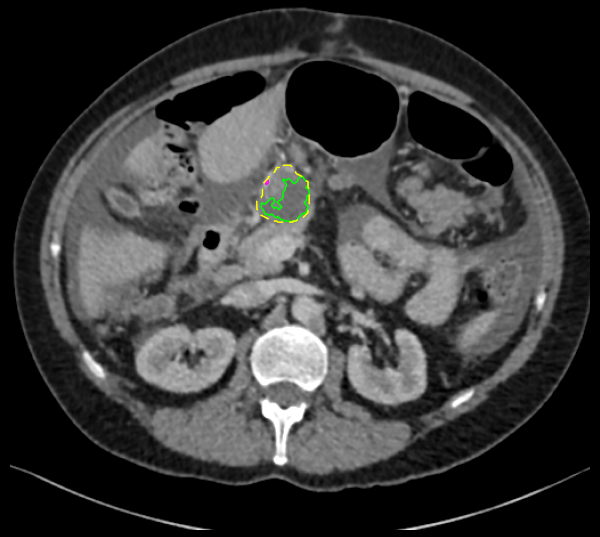
Clinical data, CA 125, radiomics, and ctDNA with external validation

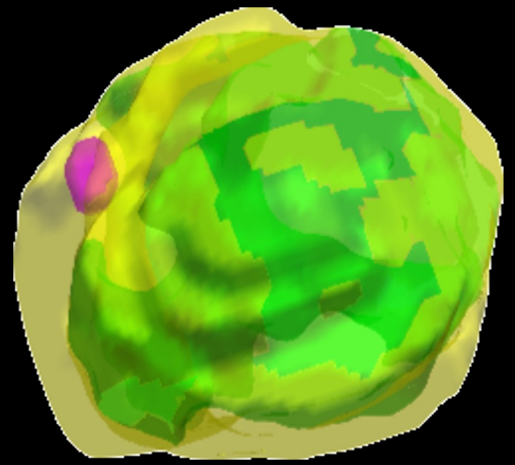


Crispin-Ortuzar M & Woitek R et al. under review *Nat Comms*

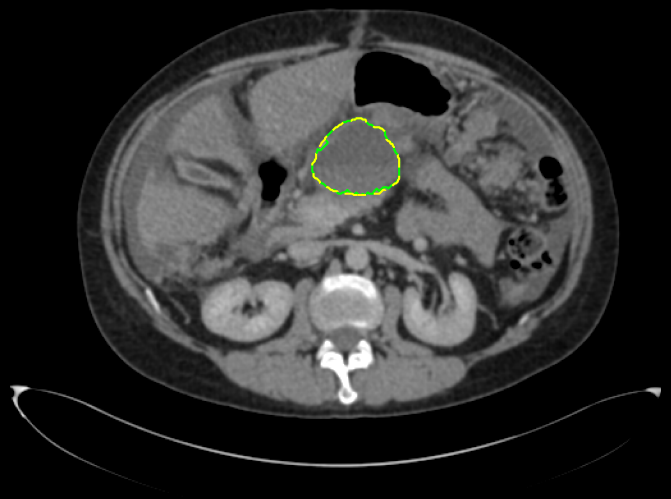
Lesser sac lesion

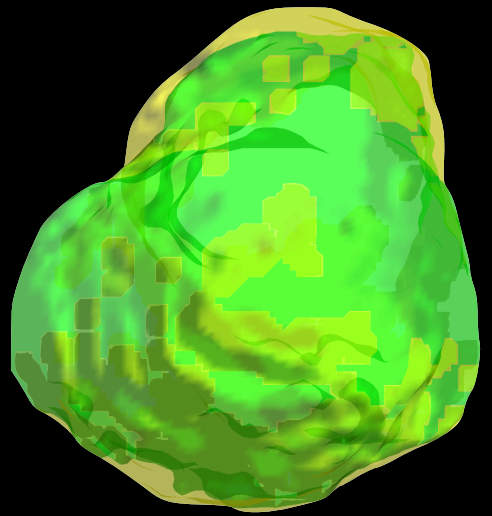
Time point 1



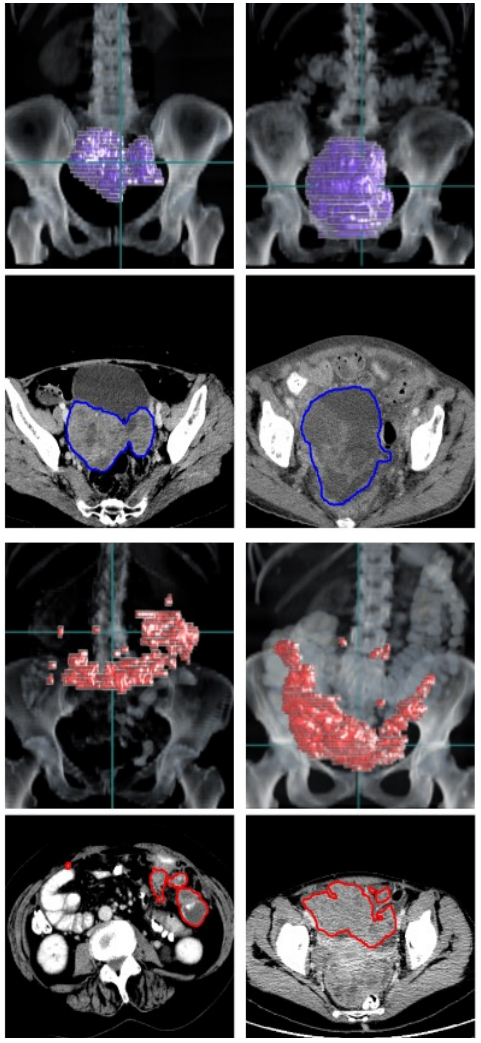


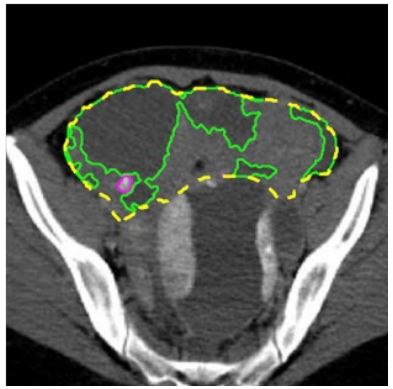
Time point 2

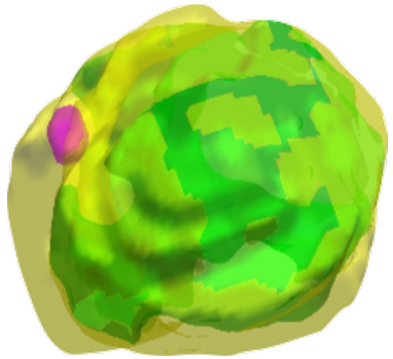




Automated segmentation Automated sub-segmentation







Improved response assessment

Overall changes in total tumour volume

Cystic vs. solid components

→ Radiomics of different tumour components

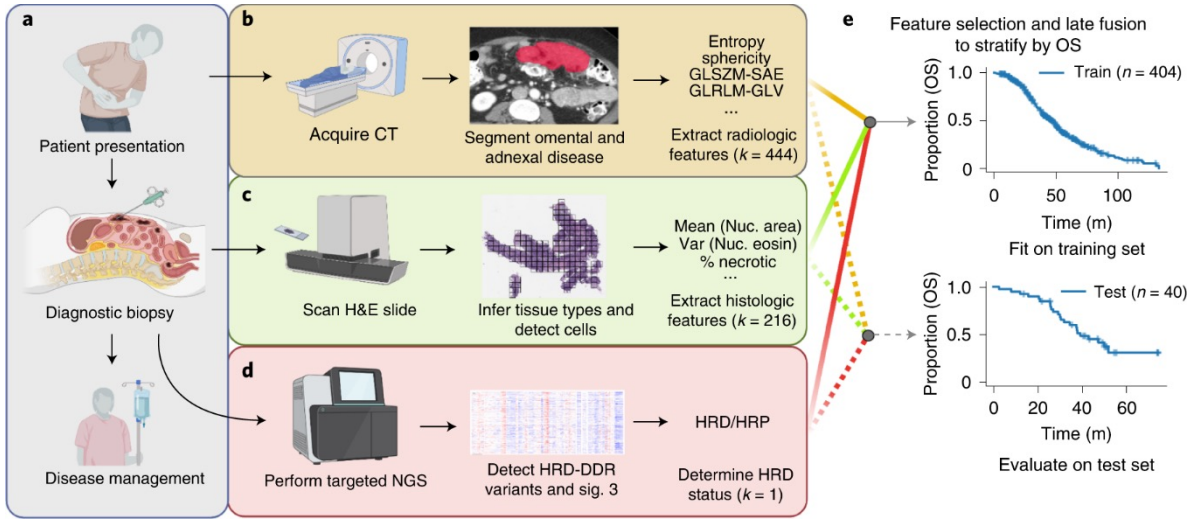
Buddenkotte et al. 2022 (manuscript under review)

L. Rundo et al. 2020 Computers in Biology and Medicine

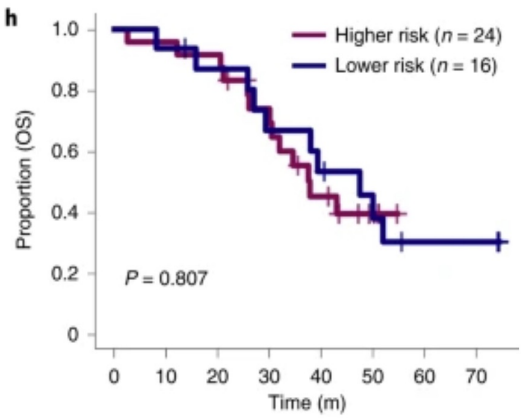
Radiogenomics for patient stratification

Patient stratification based on multiomics

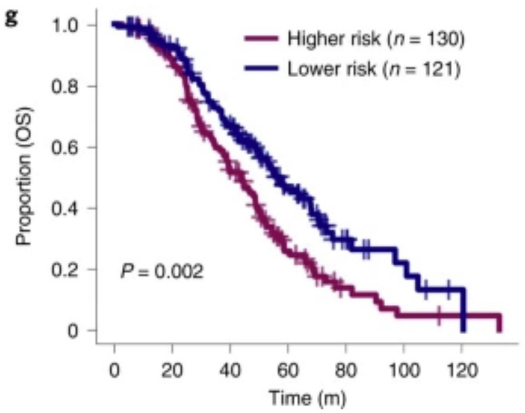
- CT
- H&E tissue sections (dig. Pathology)
- HRD/HRP (NGS)



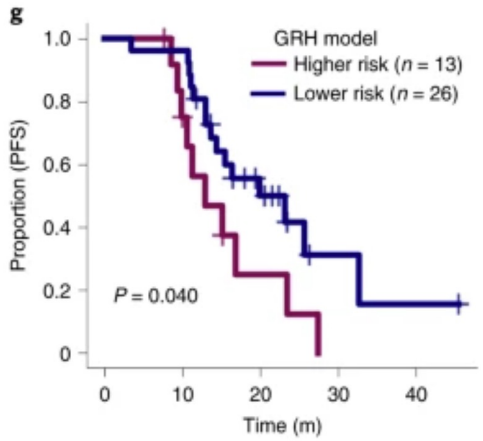
Adnexal radiomics



Omental radiomics



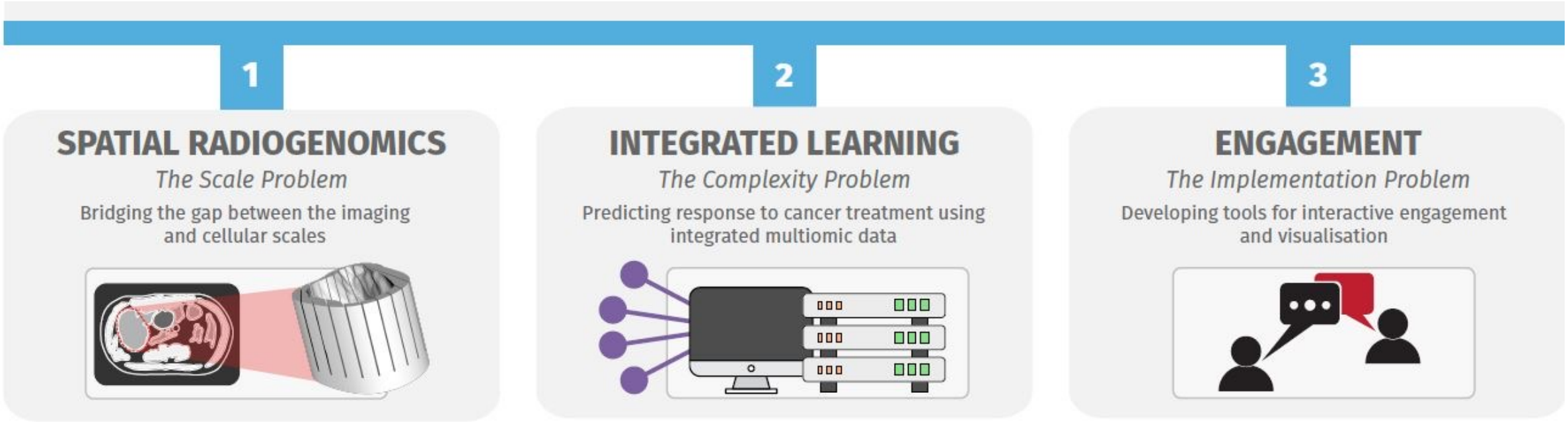
Multimodal data (incl. omental radiomics)



Boehm et al. Nat Cancer 2022

Vision (next 5 years)

Develop integrated frameworks for cancer that bridge the gap between imaging and cellular scales (research line 1), predict response to treatment (research line 2), and engage interactively with patients and clinicians (research line 3)



THANK YOU

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Delivering a New Paradigm
for Personalised Cancer Medicine

AI/Deep Learning | PDTXs | Imaging & Digital Pathology | eMR & EPIC | Molecular Signatures