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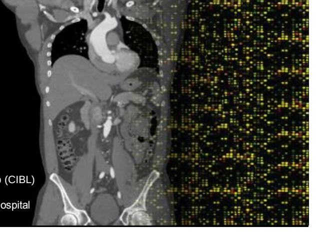
Radiomics:
The Promise of Imaging for Precision Medicine



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Disclosure Information

2016 AAPM meeting Washington, DC
Dr. Hugo Aerts

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Objectives

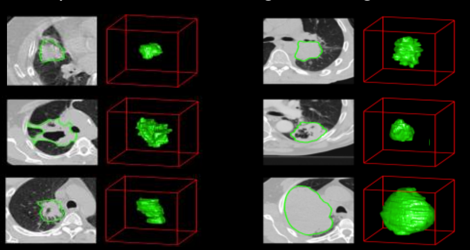
- Describe the motivation and methodology for Computational Imaging & Radiomics
- Describe biomarker quantification studies in Radiomics and Imaging-Genomics (Radiogenomics)

Imaging for precision medicine

Advantages of Imaging:
- Performed non-invasively
- Provides 3D picture of the entire cancer
- Already performed in clinical practice
- Multiple times during treatment for diagnosis, staging, radiation oncology planning, response assessment
- Captures a cancer's appearance over time and space

Disadvantages of Imaging:
- Probes the cancer at the macroscopic level
- Often qualitative not quantitative
- Very heterogeneous acquisition protocols:
  - comparisons between patients difficult
  - comparisons same patient in time difficult
- Storage of only reconstructed images (not the raw data)

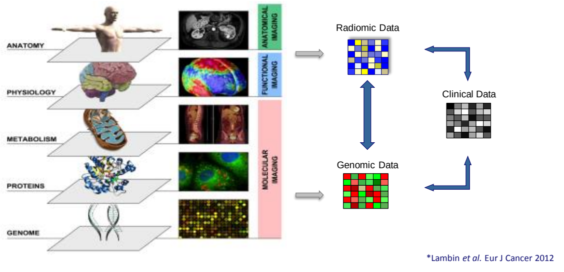
Representative CT images of lung cancer



Tumors are different

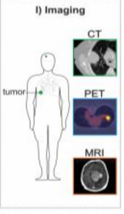
Medical imaging can capture these phenotypic differences

Multi-level patient data



*Lambin *et al.* Eur J Cancer 2012

Image-based Phenotyping



Important Challenges:
Image Acquisition, reconstruction, standardization, storage

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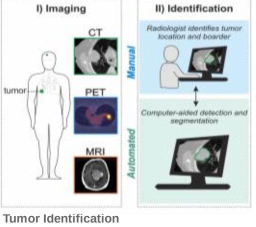
Image-based Phenotyping



Automatic detection of tumors and other abnormalities (CADe):

1) Improve diagnostic accuracy.
2) Improve speed of diagnostic reads.

(Semi) automatic segmentation:

1) Method for high throughput analysis of images.
2) Reducing the **high intra- and inter-observer variability** observed for target definition.

Tumor Identification
Identifying tumor presence, location, and extend using visual assessment and/or using automated detection (CADe) and segmentation.

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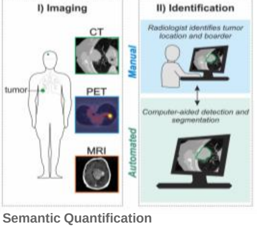
Image-based Phenotyping



Semantic Quantification
Image-based phenotyping by visual assessment of expert radiologists

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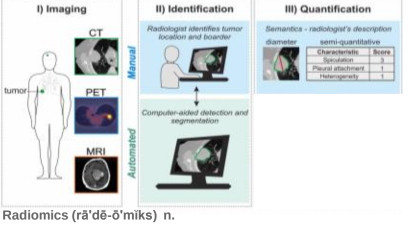
Image-based Phenotyping



Radiomics (rā'dē-ō'mĭks) n.

Radiomics aims to provide a comprehensive quantification of the imaging phenotype by extracting automated and quantitative features

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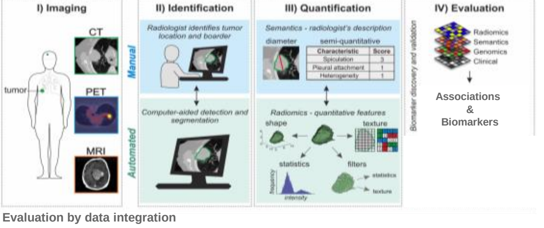
Image-based Phenotyping



Evaluation by data integration

Integration of imaging based data with genomic (Imaging-Genomics) and clinical data to evaluate associations and build prognostic / predictive biomarkers

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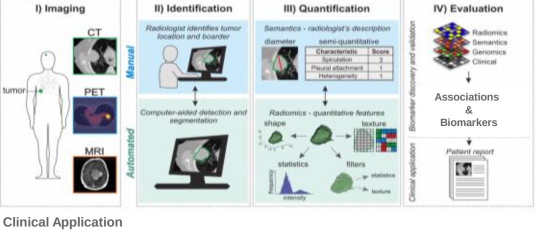
Image-based Phenotyping



Clinical Application

Application of robust and useful imaging-based biomarkers in clinical settings

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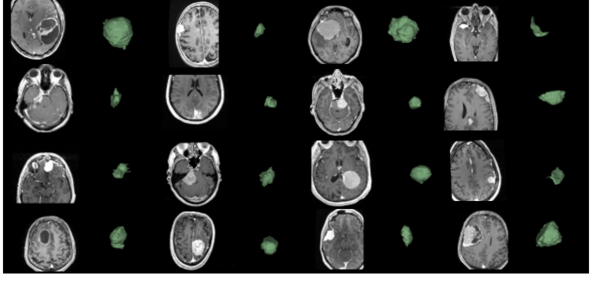
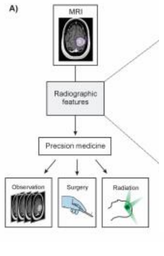
Image-based Phenotyping

(Radiomics and Imaging-Genomics examples)

Meningioma

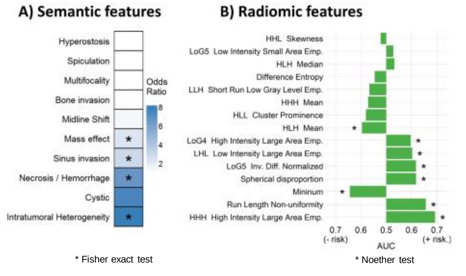


Study Design

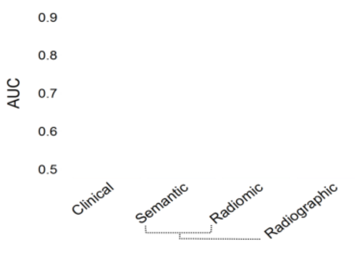


*Coroller *et al.* submitted

Univariate prediction (n=175)



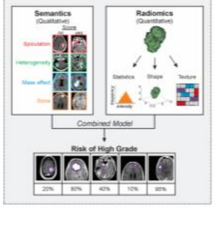
Random Forest Classifiers



training dataset (n=131), validation dataset (n=44)

*Coroller *et al.* submitted

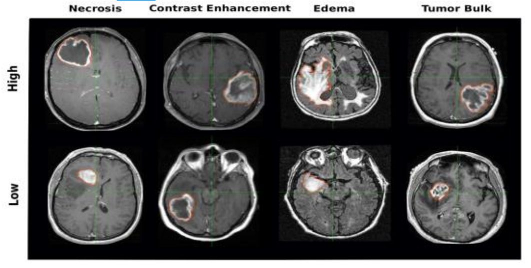
Conclusions meningioma



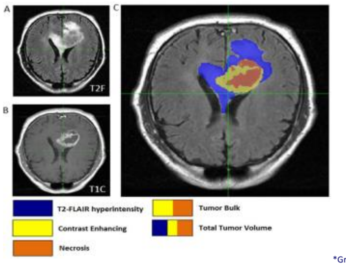
- Clinical model **could not predicted** grade
- Radiographic features did **predicted grade**
  - Semantic (simple, intuitive)
  - Radiomic (reproducible, high throughout)
- Combined model (sem. + rad.) **significantly improved** grade classification

*Coroller *et al.* submitted

Imaging-Genomics in GBM

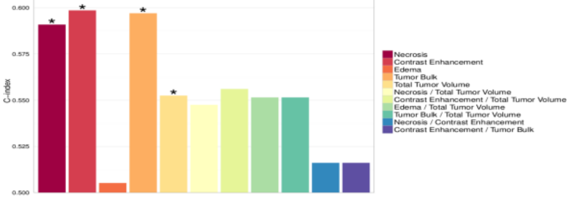


Methods: Manual delineations



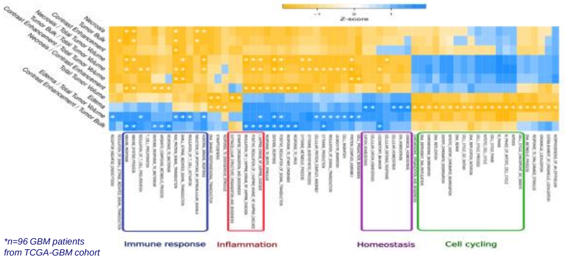
*Grossmann *accepted BMC Cancer*

Prognostic value of volumetric features



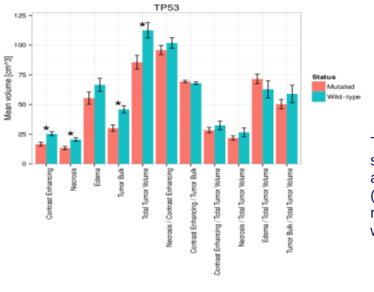
*Grossmann *accepted BMC Cancer*

Imaging-Genomics Pathway Analysis of MRI Derived Volumetric Tumor Phenotype Features in Glioblastoma



**n=96 GBM patients from TCGA-GBM cohort*

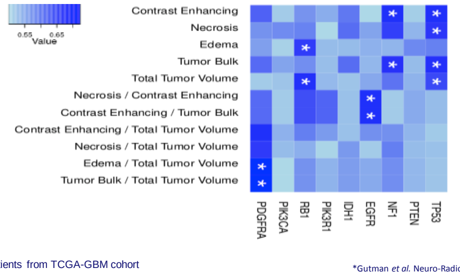
TP53 positive/negative



TP53 mutated tumors had significantly smaller CE and necrotic volumes (p=0.012 and 0.017, respectively) compared to wild-type.

*Gutman *et al.* Neuro-Radiology 2015

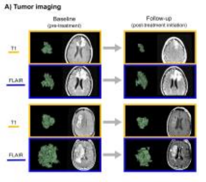
Volumetric features predict mutational status in GBM patients



n=76 GBM patients from TCGA-GBM cohort

*Gutman *et al.* Neuro-Radiology 2015

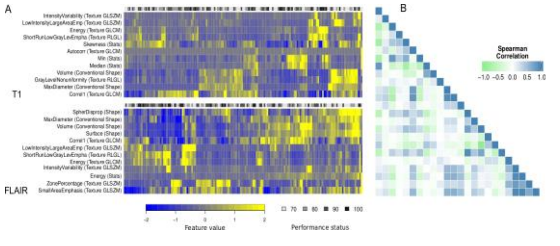
Recurrent Glioblastoma Treated with Bevacizumab



**165 patients enrolled in the phase II BRAIN trial*

*Grossman *et al.* submitted

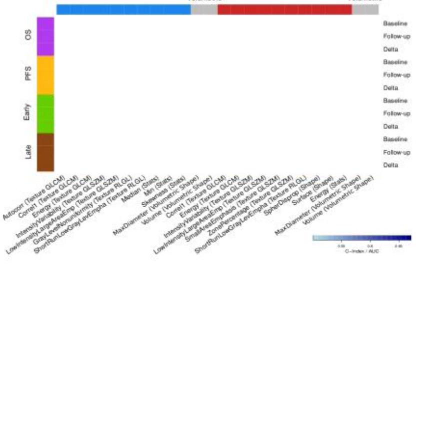
T1 and FLAIR radiomic data



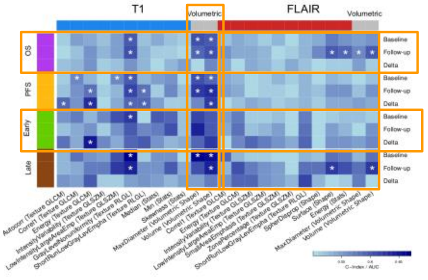
**165 patients enrolled in the phase II BRAIN trial*

*Grossman *et al.* submitted

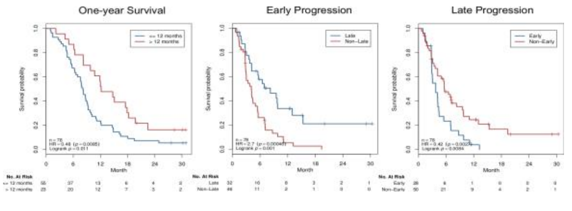
Prognostic value of T1 and FLAIR features



Prognostic value of T1 and FLAIR features



Multivariable survival and progression models derived from T1-weighted baseline imaging



These markers showed strong stratification power in independent validation data (hazard-ratio > 2; log-rank p ≤ 0.001) after adjusting for age, sex, and baseline Karnofsky performance status.

*Grossman *et al.* submitted

Radiomics: Current Status

- Imaging moves towards a computational data science (bioinformatics)
- Due to advances in imaging, quantitative imaging is currently possible
- Large retrospective and prospective potential

- Large number of imaging features defined & successfully implemented
- Feature extraction pipelines implemented in 3D-Slicer (Python / Matlab)

- Radiomics signatures are prognostic across cancer types
- Radiomics are strongly connected with genomic patterns
- Integration of multiple datasets to improve performance

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