Identify imaging biomarkers using Radiomics and Machine Learning from Multiparametric MRI

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Outlines
- The role of DWI in cancer care
- The application of radiomics and machine learning on Multiparametric MRI
  - Detection and Stratification of Prostate Cancer
  - Predicting pathologic response after preoperative chemoradiation therapy for locally advanced rectal cancer
The role of DWI in cancer care

DWI is sensitive to the arrangement, type, geometry, and permeability of cells at the micron scale due to its direct dependence of water diffusion on the tissue microstructural environment.

- Lesion Detection
- Lesion Characterization
  - Distinguish tumor from other entities such as inflammation, hemorrhage etc.
- Tumor Volume and Staging
- Treatment Response Evaluation

Apparent Diffusion Coefficient

- The monoexponential ADC model is a commonly used model to describe water diffusion behavior.
- However, it lacks biological specificity since the ADC value depends on cell density, size, shape, permeability, subcellular architecture, extracellular matrix, and perfusion effects.
- Many different tissue structures could potentially lead to the same average water molecule displacement and the same DWI signal.
- Still the ADC model performs well for cancer detection and grading in various disease sites.

Improving on ADC

- Account for diffusion anisotropy, fractional anisotropy
- Non monoexponential DWI signal attenuation, kurtosis adjusted diffusivity, biexponential model
- Compartment models
  - Two compartment model (The IntraVoxel Incoherent Motion)
  - Three compartment model (Vascular, Extracellular, and Restricted Diffusion for Cytometry in Tumours)

Multiparametric MRI + Radiomics + Machine Learning
Detection and Stratification of Prostate Cancer

There is evidence of bilateral seminal vesicle invasion, which is extensive on the right.

<table>
<thead>
<tr>
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<th>Right</th>
<th>Left</th>
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<tbody>
<tr>
<td>ADC</td>
<td>637.14</td>
<td>1400.43</td>
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<tr>
<td>Ktrans</td>
<td>0.26</td>
<td>0</td>
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Studies using ADC to predict PCa Aggressiveness

- ADC mean from a single slice
- ADC mean from the entire volume
- 10th percentile of the ADC computed from the entire lesion
- 10th percentile and ADC mean
- Various histogram-based ADC measures

Radiomics Features

- Radiomic data – 1st, 2nd and higher order statistics, extra quantitative features that result in the conversion of images into mineable data and used the data for diagnostic, prognostic, and predictive accuracy.
- First-order statistics describe the distribution of values of individual voxels without concern for spatial relationships.
- Second-order statistical descriptors generally are described as "texture" features; they describe statistical interrelationships between voxels with similar (or dissimilar) contrast values.

Texture Features
Artificial Neural Network (ANN)

Using the discriminant features set as input, an ANN was trained and optimized for detection of DILs and NTs.

**ANN training, optimization and validation:**
Leave-one-out method was used for training, optimization, and evaluation.

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ANN Training and Optimization

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Apply ANN to Tumor Grading

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Texture Features in ADC and T2

217 men, MR within 6 months of prostatectomy, Validated against whole-mount sections for histopathologic examination

ROC curves for GS 3 + 4 vs. GS 4 + 3 occurring in (A) PZ and TZ and (B) PZ only.

Deep Machine Learning – Data Preprocessing
Convolutional Neural Network - Feature Visualization

Activation Outputs at Epoch 300

Activation Outputs at Epoch 700

Sharper clearer features when training progresses.
Predicting pathologic response after preoperative chemoradiation therapy (CRT) for locally advanced rectal cancer

Selection of complete responders after chemoradiation for locally advanced rectal cancer

- Locally advanced rectal cancer (LARC), the standard-of-care treatment is preoperative concurrent chemoradiation treatment (CRT) followed by total mesorectal excision
- After CRT, approximately 15% to 27% of patients show a pathologic complete response
- 5-year follow-up were favorable for the nonsurgical group, with an overall and disease-free survival of 93% and 85%, respectively
- Noninvasive approaches to identify complete responders for an alternative surgical treatment such as sphincter-saving local excision.
Diffusion-Weighted MRI for Selection of Complete Responders

Identification of a complete tumor response after CRT using T2 vs. T2+DWI

Residual Tumor vs. Fibrosis

- 120 consecutive patients who were treated for locally advanced rectal cancer
- Sensitivity for identification of a complete response improved by 16–52% for the three readers
- Substantial reduction in the number of equivocal scores (CL) and an improved interobserver agreement

MultiParametric MRI of 2 male patients, with mid-rectum cancer at stage of cT3N+M0

- All 48 patients received MR examinations 1 to 2 weeks before the chemoradiation and 1 week before surgery
- A total of 203 quantitative imaging features were obtained for each patient
Differences between the pCR versus non-pCR groups

- None of the quantitative measures from anatomical T1, T2 images showed statistically significant differences.
- The GR group had lower mean ADC (0.91 ± 0.11) × 10⁻³ than those showing non-favorable responses (0.97 ± 0.09) × 10⁻³.
- The higher portions of the histogram percentiles (50%-80%) were lower in the pCR groups than in non-pCR.
- All the texture measures from DCE MRI showed statistically significant differences between GR and non-GR group.

The ROC curves of selected individual parameters and combined feature sets in predicting pCR vs. non-pCR (A) and GR vs. non-GR (B)

Conclusions

DWI is one of the most effective MR modality for cancer diagnosis and prognosis considering its sensitivity to tissue microstructure. However, diffusion dynamics is quite complicated and depends on many factors including cell density, size, shape, permeability, subcellular architecture, extracellular matrix, and perfusion effect.

The wealth of radiomics extracted from multiparametric MR images should be further explored to help tailoring the treatment into the era of personalized medicine.
Thank you!