Radiomics and Radiogenomics Modeling with Machine Learning
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Why 'omics outcomes modeling?

Population-based dose response

Too shallow!
The Pan-Omics of Oncology

Collect Specimen, Screen Specimen, Aggregate Data, Analyze Data

Outcomes Modeling Schemes

Clinical endpoint (phenotype)

Top-down

Integrative models

First principle mechanisms

Bottom-up

Biophysical interaction (genotype)

Integrative radiobiological modeling

TCP/NTCP are multi-factorial and depend on: radiation dose and patients' genomic (radiogenomics) and imaging (radiomics) characteristics before & during radiotherapy.
**Radiogenomics NTCP Modeling: Dose + genomics**

Rectal bleeding in prostate cancer

Coates et al., RO, 2015

- CNV V10, V20, D50 and XRCC1 CNV

**Panomics NTCP Modeling: Dose + biologics + imaging**

ALBI changes in liver cancer

El Naqa et al, IJROBP, 2018 (CME article)

- ALBI changes in liver cancer

**Outcome modeling by Machine learning (ML)**

- **Generative models**
  - Model class-conditional PDFs and prior probabilities (Bayesian networks, Markov models)
    - To predict you need to know the system

- **Discriminant models**
  - Directly estimate posterior probabilities (logistic regression, neural networks, CNN, random forests, SVM)
    - Predict without knowing the system
Multi-Objective Generative Models

A BN can be used to model multiple outcomes simultaneously, which provides additional opportunities for finding appropriate treatment plans to solve the trade-off between competing risks.

Luo et al, Med Phys, 2018 (Editor's Choice)

Human-in-the loop: Pre/During Treatment BNs for LC and RP2 Prediction

Prediction of tumor local in lung cancer using DNN

Composite neural network architecture
**Deep learning architectures for joint actuarial prediction of LC and RP2**

- Cui et al. AAPM 2020

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**How to build an ML/DL model?**

- Depending on the level of evidence
  - Selection appropriate learning algorithms
  - Validation and evaluation (TRIPOD criteria)
    - Internally (cross-validation schemes)
    - Externally (independent datasets)
  - Provide interpretation of machine learning prediction

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**ML validation**

- Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis (TRIPOD)

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Conclusions

- Radiomics and radiogenomics offer new opportunities to develop better TCP/NTCP models and for personalizing radiotherapy.
- Machine/deep learning techniques can improve feature selection and statistical learning in radiomics/radiogenomics analytics and modeling radiotherapy outcomes.
- Main challenges for radiomics/radiogenomics modeling:
  - Harmonization and optimization of data integration methods.
  - Uncertainties in data and model building schemes.
  - Proper validation (TRIPOD criteria) and robustness for clinical decision support.
  - Better interpretation of radiomics/radiogenomics models is still lagging.
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