Digital Twins of Cancer Patients: A New Perspective to Support Clinical Decisions

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Learning Objectives

• Identify the challenges and opportunities of AI applications in clinical decision support

• Understand a digital twin-based clinical decision support tool for radiation oncology
Multimodality data at spatial-temporal scales

**Clinical:** EHR, lab results, diagnoses, procedures, pathology/histology data, radiology images, and microbiology data

- **Mobile health:** wearable devices, fitness trackers, sensors, and apps

- **Molecular profiling:** genomic and genetic testing data, and multi-omics data

- **Social media**

- **Environmental**

- **Lifestyle**

- **Dietary**

- **Family history**

- **Medication**
Challenges

- **Data challenges**: generating and acquiring high-volume, high-quality, multiscale data

- **Modeling and integration challenges**: seamlessly integrating data-driven and mechanistic modeling

- **Ethical and community challenges**: ethical biases, privacy concerns, and patient engagement
A Digital Twin for Each Cancer Patient
What is a Digital Twin?

- A digital twin is a **synchronized digital replica** of a physical system, which is used to **monitor, model, and fine-tune performance** of processes, people, places, systems and devices.

- Digital twins can be used for **in silico** simulations:
  - *What if* the engine runs 50% hotter?
  - *What if* the wind speed is 10 times faster?


- Aerospace engineering, manufacturing, construction, automotive, healthcare
Why Digital Twins in Radiation Oncology?

• A patient-tailored model that incorporates genetic, molecular, clinical, environmental, and social factors to predict individual patient’s status for:
  
  – Adaptive radiation therapy based on multimodal real-time data
  
  – Predictive modeling of treatment response short-term and long-term
  
  – Early intervention based on precise monitoring of adverse effects
  
  – Virtual clinical trials
The Big Picture

Personal Phenotypes

- Personal History
- Family History
- Genome
- Transcriptome
- Proteome
- Immunome
- Metabolome

Digital Twin Simulation Using HPC

- Clinical
- Behavioral
- Imaging
- Physiological
- Exposome
- Microbiome

Choose a care path

- Hormone Therapy
- Radiation Therapy
- Immunotherapy
- Surgery
- Targeted Therapy
- Chemotherapy

Personalized Care Trajectories

Shared Decision Making

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Significance

Spatial Scale  Time Scale

Predictions  Patient Care Decision
Innovation

• Connected multiscale multimodality data
• New knowledge of healthy and disease states at spatial-temporal scales
• Computational and mathematical models for dynamic multiscale systems in biology
• Computational learning frameworks

Peng et al., Archives of Comp Methods Eng, 2020
Multiscale Modeling

- Development of multiscale representations
  - PK-PD model of drug-tumor interactions to predict tumor evolution
  - Physics-informed ML on clinical and imaging data to develop dynamical systems
  - Deep graph similarity learning to identify similar patients

Ghaffarizadeh et al. (2018)
DOI: 10.1371/journal.pcbi.1005991

Guy et al. (2019)
DOI: 10.1038/s41598-019-46296-4
Personalized Decision Support

- User-in-the-loop deep learning for personalized clinical decision support
- Leveraging knowledge graph and HPC for optimal treatment pathways
Conclusions

- Digital twins will enable predictive oncology for cancer patients
- Understanding cancer biology and patient care trajectory is the key
- Modeling of multiscale multimodality data is challenging
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