Understanding and reducing the radiation exposure of CT scanners

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Acknowledgements

Marquette University
Hongfeng Ma, PhD
Michael Offe
Dong Hye Ye, PhD

Medical College of Wisconsin
Sara Principi, PhD
Stacy O'Connor, MD
Nghia Vo, MD
Yu Liu, PhD

Varian Medical Systems
Petr Jordan, PhD
Alex Maslowski, PhD
Todd Wareing, PhD
Phil Adamson

Children's Hospital of Wisconsin
Joseph Ackerman
Linda Strain

Stanford University
Adam Wang, PhD

This work was supported by NIH grant U01EB023822. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health

Computed Tomography (CT) Imaging

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- Very important for diagnosing and monitoring disease
- Has small risk due to X-ray radiation exposure
- Biomedical Engineers are developing tools to quantify and reduce CT radiation dose

Outline

- Background on CT imaging and radiation
- Challenges of quantifying radiation dose
- Our research to provide rapid, personalized radiation dose estimates

CT Imaging System

- X-ray imaging system that rotates about the patient
- Thousands of x-ray images acquired in each rotation
- Mathematical algorithms reconstruct CT images

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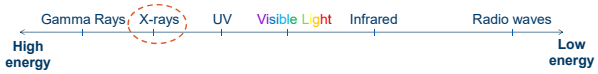
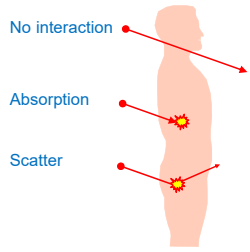
X-rays are Electromagnetic Radiation



Interaction Between X-rays and the Body

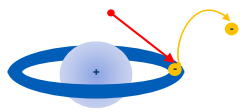


Probability of X-ray interaction varies across materials

Provides contrast between tissues in X-ray or CT images

X-ray interactions deposit energy in the body **= Radiation Dose**

Effects of Radiation on the Body

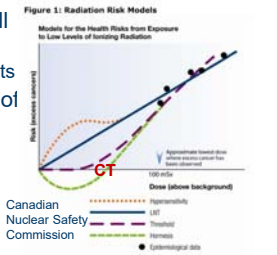


Hydrogen atom → Hydrogen ion

- Ionization turns water into free radicals
- Free radicals **may** damage DNA
  - Or be stabilized by antioxidant
- Damaged DNA **may** lead to a mutation
  - Or insignificant damage
- Mutation **may** develop into cancer
  - Or may be repaired

Radiation Risk

- High radiation dose will cause cell damage
  - Burns, hair loss, cell death, cataracts
- Low radiation dose (CT) has risk of causing cancer
  - The risk is unknown and difficult to estimate
  - **The risk is thought to be small**
  - **The benefit of CT is large**



Radiation Dose vs Radiation Risk

Radiation Dose:
Amount of energy absorbed by the tissue

Radiation Risk:
Likelihood of adverse effect

Our research focus

Radiation Overdosing Incident 2009

- Several hundred patients
- Erroneously high radiation dose
- Prompted mandatory radiation dose reporting in many states
- But estimating patient radiation dose is challenging

The New York Times
Radiation Overdoses Point Up Dangers of CT Scans

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Current Dose Estimation Methods

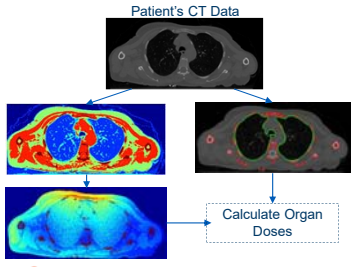
- Report radiation output by scanner
- Dose to a plastic cylinder

We want to quantify radiation dose to a patient's organs

Gammex

Estimating Patient Organ Dose

- Create computational model of patient
- Simulate dose map
  Challenge! High computation
- Identify organs to calculate organ dose
  Challenge! User input



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Patient-Specific Dose Reporting

Develop software tool to estimate organ radiation doses

- Patient Specific
- Accurate
- Rapid
- Automated

Routine

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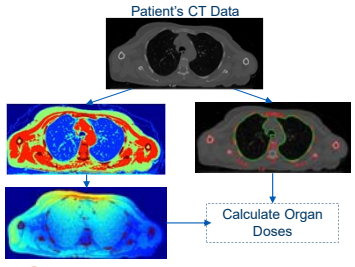

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  Rapid Solver
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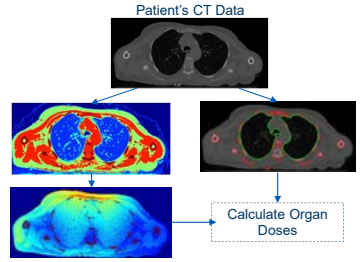

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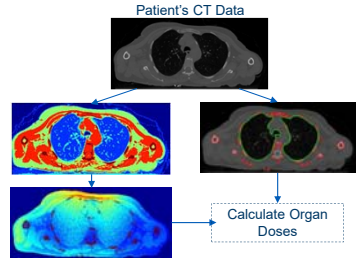

Estimating Patient Organ Dose

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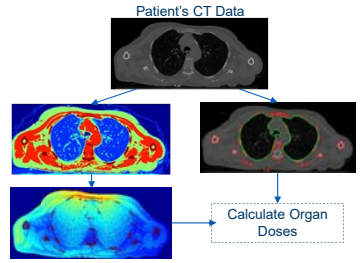
  Artificial Intelligence



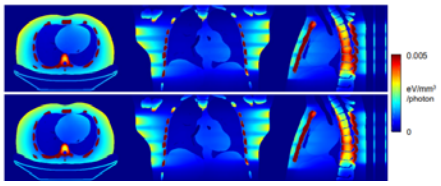
Developing Rapid Dose Map Solver

- Based on Acuros (Varian Medical Systems) software used for radiation therapy planning
- Optimized algorithm parameters for CT radiation
- Developed CT scanner models

Validating Rapid Dose Map Solver

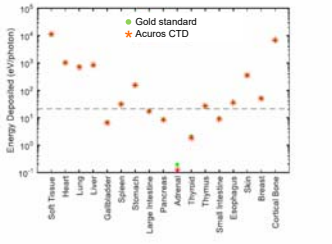
Gold Standard (687 CPU hours)

Acuros CTD (23 seconds)



A. S. Wang, et al., "A fast, linear Boltzmann transport equation solver for computed tomography dose calculation (Acuros CTD)," Medical Physics, 46 (2), pp. 925-933, (2019).

Validating Rapid Dose Map Solver



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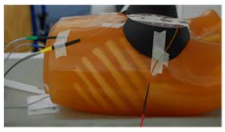
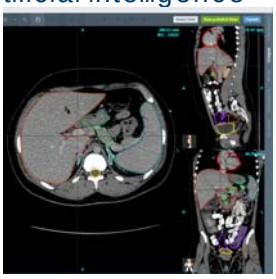
Validating Rapid Dose Map Solver

Next step:
Experimental
Validation



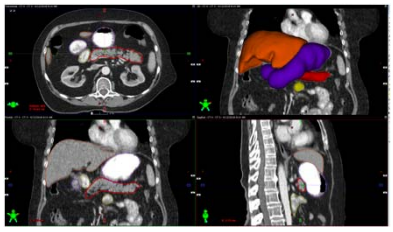
Identify Organs with Artificial Intelligence

- 100 pediatric CT datasets
- Organs manually identified by experts
- Used to train deep learning algorithms



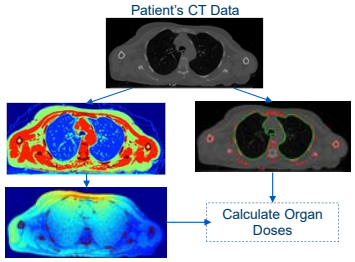
Identify Organs with Artificial Intelligence

Next step:
Quantify
performance on
test datasets



Putting it all together

- Combine dose map and organ identification algorithms
- Estimate and analyze organ doses for 400 pediatric CT datasets
- Compare to existing methods



How will this tool help?

- Routine patient-specific radiation dose reporting
- Improved identification of overdosing incidents
- Provide data for understanding CT risk
- Improved optimization and standardization of CT imaging protocols
- Facilitate development of new methods to reduce radiation dose

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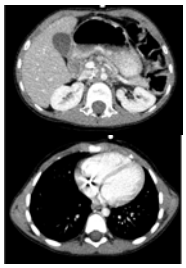

FDA CT Dose Recommendations

- Ask doctor how an X-ray or CT will help
- Don't refuse an X-ray or CT exam
- Don't insist on an X-ray or CT
- Keep record of X-ray and CT exams to avoid unnecessary repeats

https://www.fda.gov/ForConsumers/ConsumerUpdates/ucm095505.htm