Radiation Physics Center 2021 Report

A report from the Childhood Cancer Survivor Study

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THE UNIVERSITY OF TEXAS
MD Anderson Cancer Center
Making Cancer History®

CCSS
Childhood Cancer Survivor Study

Radiation Physics Center Team

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- Our team has a well-established decades long collaboration with CCSS
  - Includes medical physicists and dosimetrists, research data coordinators, computational scientists and programmers, physics technicians, graduate students, and administrative staff

Roles of the Radiation Physics Center

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- Provide input during proposal development regarding level of dosimetry detail needed and/or achievable for planned analyses
- Maintain secure database with scanned indexed copies of the complete radiation therapy (RT) records from CCSS institutions
- Calculate organ and body-region doses from RT for study participants
- Assist the investigators in understanding and using the RT data in analyses and manuscripts

Radiation Dosimetry Process

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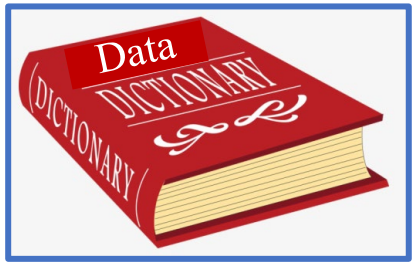
1. Abstract patients' RT records **Cohort dosimetry N > 13,000**
2. Reconstruct RT fields on in-house phantom scaled to age at RT
3. Calculate dose to region or organ of interest
4. Quality assurance of computed doses
5. Create output files and documentation (data dictionary)
6. Provide data to FH statistics center for distribution to individual investigators (with approved concept proposals)



CNS Example Case

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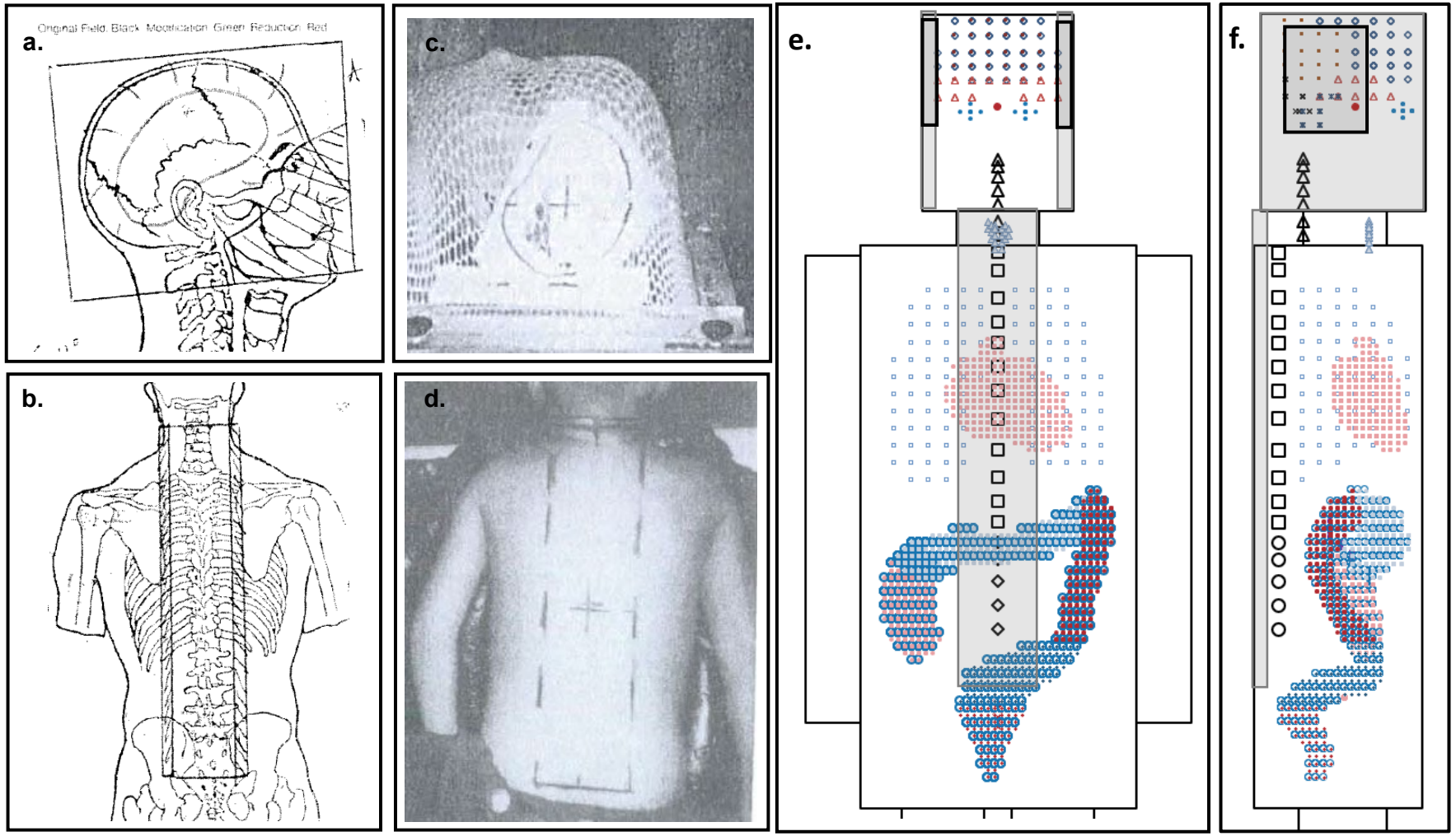
Translation of patient chart data to reconstructed fields on age specific phantom



Adapted from Howell et al. Radiat Res. **2019.** 192(2):169-188

In Progress and Completed CCSS Dosimetry

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In-progress Organ Dosimetry	Data Calculating
Colorectum (ascending, descending, transverse, rectum)	D_m, V_5, V_{10}, V_{20}, V_{30}

Completed Organ/Region Dosimetry	Data Reported
Body regions + brain 4 segment	MaxTD, SH, SL
eyes/lenses*	D_m
Kidneys (right and left)	D_m
Lungs†*	D_m
Ovaries (right and left)	D_m
Pancreas (whole)*	D_m V_{20}, V_{30}
Pancreas (head, body, tail)*	D_m
Pituitary*	D_m
Testes	D_m
Uterus	D_m
Thyroid(right and left)*	D_m
Heart (aorta, arteries, valves, ventricles)	D_m, V_5, V_{20}

Maximum target dose (maxTD), stray high (SH), stray low (SL), Mean dose (D_m), percent volume ≥ 5 Gy (V_5), ≥ 20 Gy (V_{20}) and ≥ 30 Gy (V_{30})

**RT records for three institutions were received more recently.*

We are systematically updating organ dosimetry

What's next

- Thyroid
- Pancreas
- Pituitary

†More sophisticated organ modeling is needed

Recent and Ongoing Research
Dosimetry Enhancement

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Computational Phantom Enhancement

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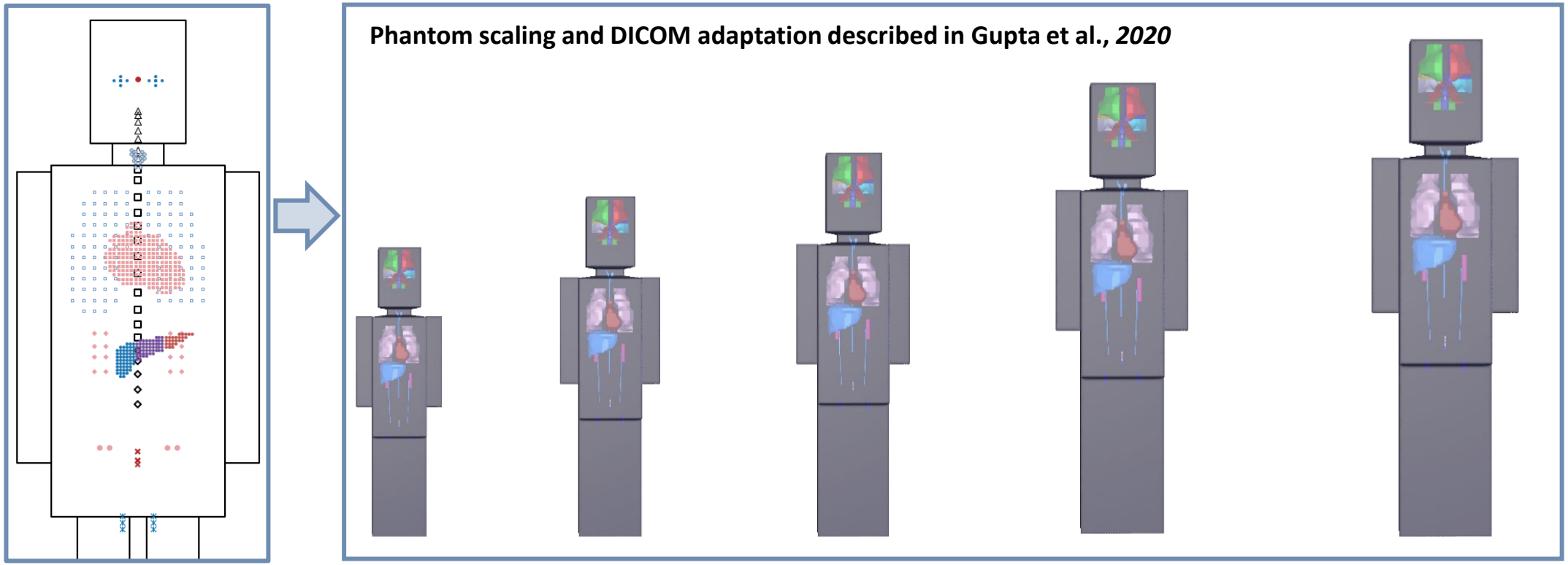
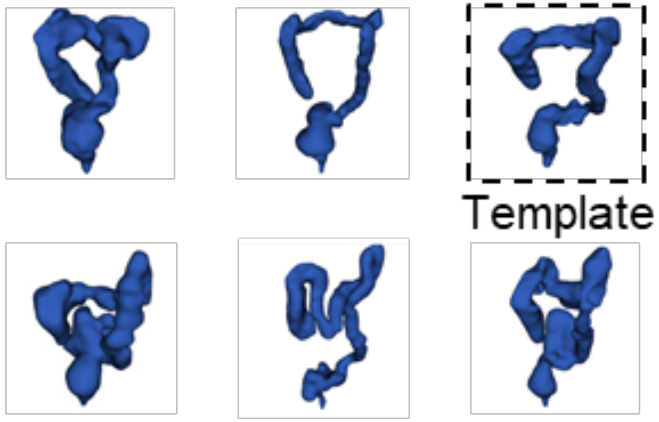
- For more than two decades, we have used an age-scalable computational phantom (modeled on FORTRAN) whose organs are represented by 3D grids of points
- We updated our phantom to DICOM format, allowing it to be used and scaled within a commercial RT treatment planning system

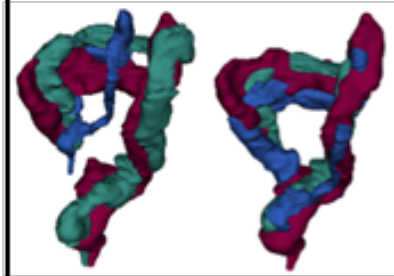


Model Development

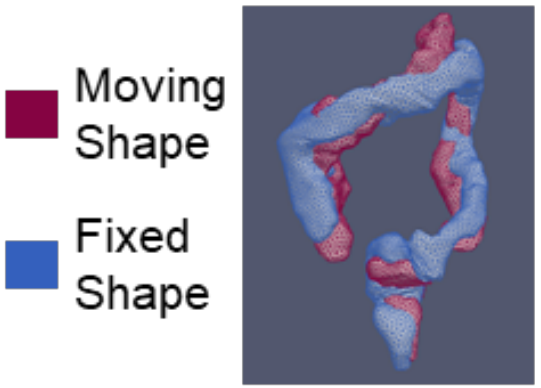
A Data pre-processing and anatomical template selection



B Shape Normalization



C Registration using constrained sTPS-RPM



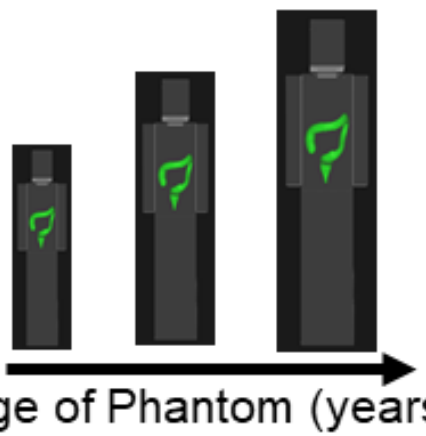
D PCA-based SSM

σ_1^2 = mode variance of the 1st PCA mode

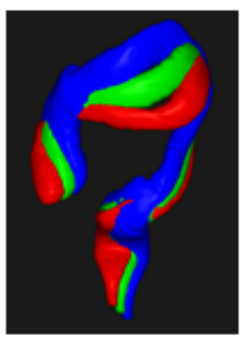
Model Integration

E Register SSM with MDA-LE phantom

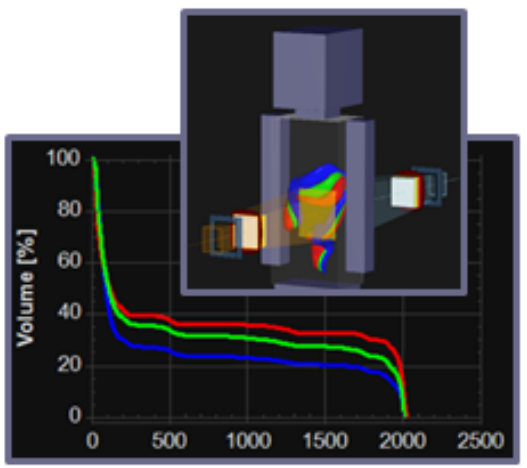
F Integrate SSM with MDA-LE phantom scaling framework



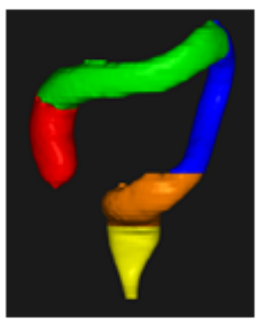
G Generate alternative models with SSM



H Dosimetric analysis



I Add substructures



Colorectum model development and validation described in Owens *et al.* Radiother Oncol. ***In Review***

Heart Model Enhancement

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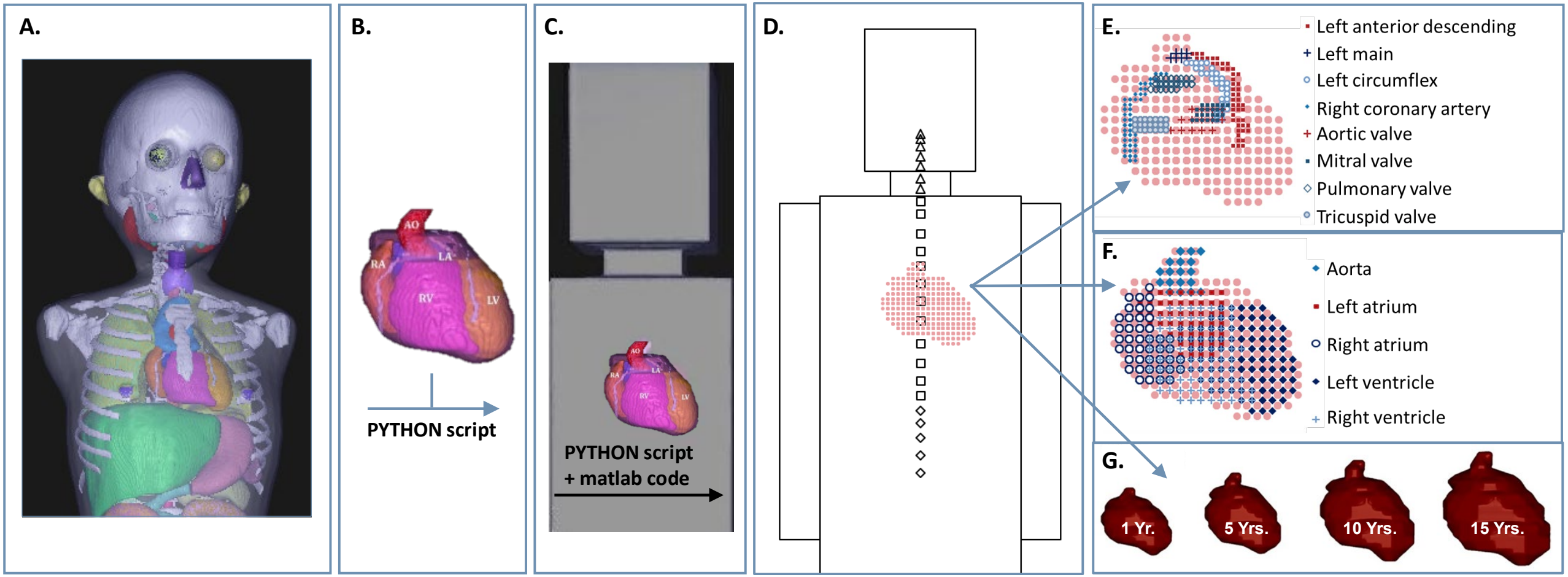

- Heart and substructure (arteries, atria, valves, ventricles) dosimetry completed for CCSS (and SJLIFE)

Heart model development and validation described in Shrestha *et al.* Radiother Oncol. **2020** 153:163-171

Phantom and organ scaling described in Gupta *et al.* Biomed. Phys. Eng. Express. **2020** 6(6):2057-1976

Substructure Low Dose Response

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Low RT mean doses 5 – 9.9 Gy to specific substructures associated with increased risk of:

Coronary Artery Disease

- RCA - RR 2.6, 95% CI 1.6 – 4.1
- LAD - RR 1.9, 95% CI 1.1 – 3.3
- left ventricle - RR 2.2, 95% CI 1.3 – 3.7

Heart Valve Disease

- Aortic valve - RR 4.6, 95% CI 1.5 – 14.0
- Tricuspid valve - RR 5.5, 95% CI 2.0 – 15.1
- RCA - RR 3.5, 95% CI 1.5 – 8.3
- Left ventricle - RR 3.4, 95% CI 1.3 – 8.0;
- Right ventricle - RR 8.4, 95% CI 3.7 – 19.0

Arrhythmia

- RCA - RR 2.0, 95% CI 1.0 – 4.1

Heart failure

- None

Personalized Risk Prediction to Reduce Cardiovascular Disease in Childhood Cancer Survivors

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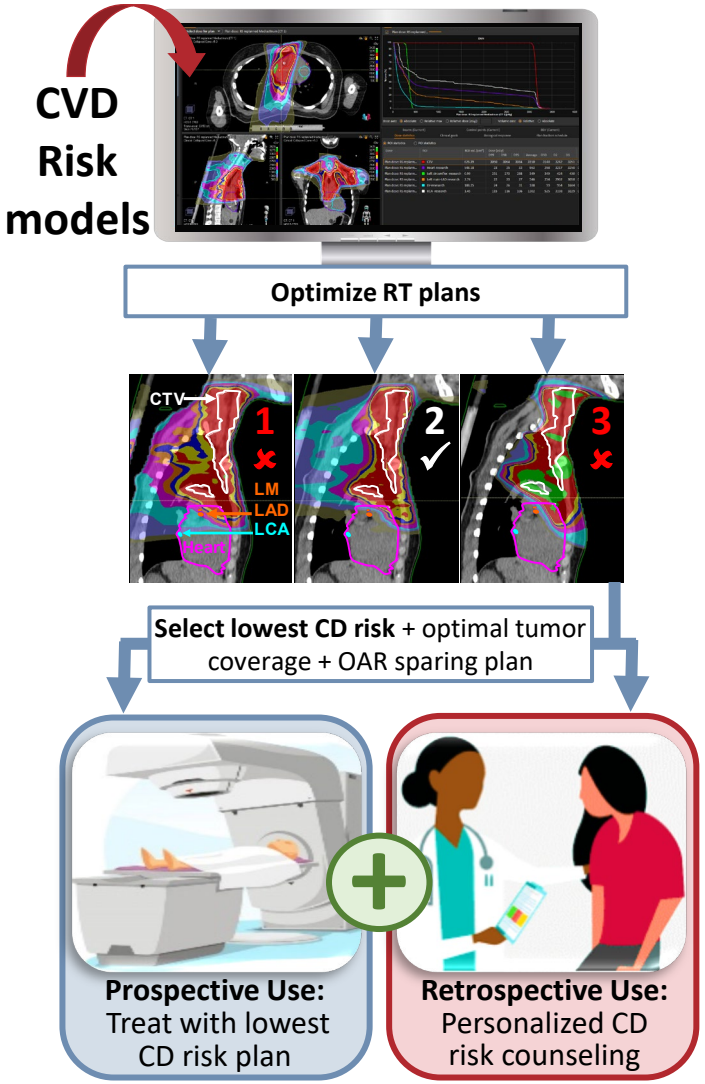
- Development (SJLIFE), validation (CCSS) and clinical translation of cardiac substructure level cardiovascular disease risk prediction models



Howell, Mulrooney, Yasui (MPI): 1R01CA261750-01A1, NIH/NCI, 4/2022-3/2026

References

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Methods Publications - Cohort Dosimetry

Stovall, M, Weathers, R, Kasper, C, Smith, SA, Travis, L, Ron, E and Kleinerman. Dose reconstruction for therapeutic and diagnostic radiation exposures: use in epidemiological studies. Radiat Res. 166:141-157. **2006**

Howell RM, Smith SA, Weathers RE, Kry SF, Stovall M. Adaptations to a generalized radiation dose reconstruction methodology for use in epidemiologic studies: An update from the MD Anderson Late Effect Group. Radiat Res. 192(2):169–188, **2019**. PMCID: PMC8041091

Gupta AC, Shrestha S, Owens CA, Smith, SA, Qiao Y, Weathers RE, Balter PA, Kry SF, Howell RM. Development of an Age-scalable 3D Computational Phantom in DICOM Standard for Late Effects Studies of Childhood Cancer Survivors. Biomed. Phys. Eng. Express 6(6). **2020**. PMC8475741

Shrestha S, Gupta AC, Bates JE, Lee C, Owens CA, Hoppe BS, Constine LS, Smith SA, Qiao Y, Weathers RE, Yasui Y, Court LE, Paulino AC, Pinnix CC, Kry SF, Followill DS, Armstrong GT, Howell RM. Development and validation of an age-scalable cardiac model with substructures for dosimetry in late effects studies of childhood cancer survivors. Radiother Oncol. 153:163-171. **2020**. PMC8132170

Shrestha S, Bates JE, Liu Q, Smith SA, Oeffinger KC, Chow EJ, Gupta AC, Owens CA, Constine LS, Hoppe BS, Leisenring WM, Qiao Y, Weathers RE, Court LE, Pinnix CC, Kry SF, Mulrooney DA, Armstrong GT, Yasui Y, Howell RM. Radiation therapy related cardiac disease risk in childhood cancer survivors: Updated dosimetry analysis from the Childhood Cancer Survivor Study. Radiother Oncol 163:199-208. **2021**. PMC9036604

Gupta AC, Shrestha S, Owens CA, Smith, SA, Qiao Y, Weathers RE, Netherton T, Balter PA, Kry SF, Followill DS, Griffin KT, Long JP, Armstrong GT, Howell RM. Body region-specific 3D age-scaling functions for scaling whole-body computed tomography anatomy for pediatric late effects studies. Biomed. Phys. Eng. Express 8(2). doi: 10.1088/2057-1976/ac3f4e. **2022**. PMID: 34874300

2022 Conference Presentations

Owens *et al.* Childhood Cancer Survivor Study (CCSS). Oral Presentation. European Society of Radiation Oncology 2022 Annual Meeting, Copenhagen, 5/2022

Owens *et al.* Childhood Cancer Survivor Study (CCSS). Oral Presentation. Finalist, Early-Stage Investigator Symposium. American Association of Physicists in Medicine 2022 Annual Meeting, Washington DC, 7/2022

Childhood Cancer Survivor Study

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- The Childhood Cancer Survivor Study is an NCI-funded resource (U24 CA55727) to promote and facilitate research among long-term survivors of cancer diagnosed during childhood and adolescence.

- Investigators interested in potential uses of this resource are encouraged to visit:

http://ccss.stjude.org


Thank you