Radiation Physics Center 2025 Report

A report from the Childhood Cancer Survivor Study

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Division of Radiation Oncology ♦ Department of Radiation Physics ♦ Late Effects Group

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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

Rebecca Howell, PhD, DABR
Director, Medical Physicist

Susan A. Smith, MPH
Associate Lab Director

Rita Weathers, MS
Data Integration Developer

Samantha Murray, BS
Sr. Research Coordinator

Tera Jones, BS, MBA, CMD
Research Dosimetrist

Andrew Filson, degree
Data Integration Developer

Marilyn Stovall, PhD
Founder

Lab Trainees

Constance Owens, PhD
Post-doctoral Fellow

Sogand Sadeghi, PhD
Post-doctoral Fellow

Taylor Meyers, MS
PhD Student

Lab Alumni

Aashish Gupta, MS
PhD Student

Suman Shrestha, PhD
Medical Physics Resident

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

Body Region Dosimetry Available for Overall Cohort

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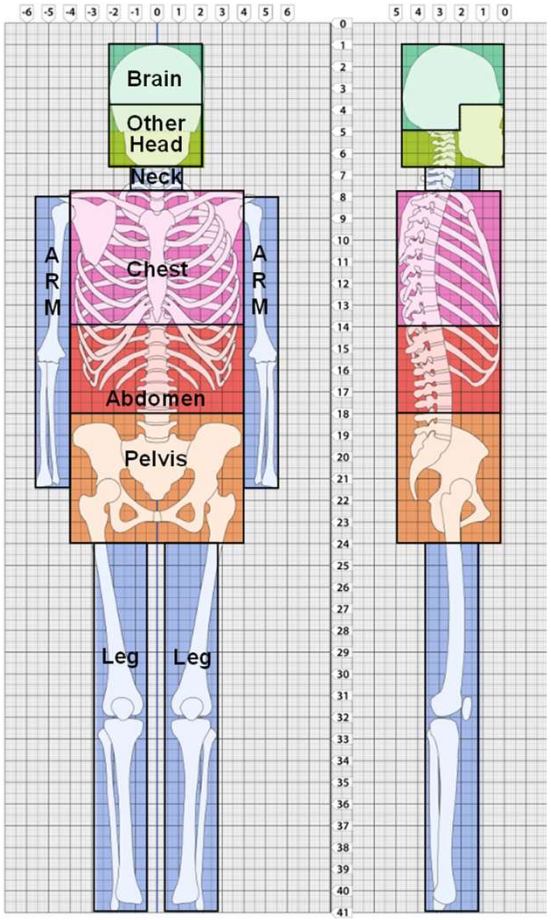

Body Region dosimetry includes for Y/N and dose for brain, other head, neck, chest, abdomen, pelvis, leg, arm regions

If RT is directed at a region (Y), dose is reported as

- Maximum target Dose (maxTD) is the maximum delivered target dose within the treated region, which is taken as the total dose from all overlapping fields within the treated region.

If RT is not directed at a region (N), stray radiation is reported

- The body-region dosimetry method estimates stray dose by assigning regions that were not directly treated based on their proximity to the treated region as being either
  1. Stray High (200 cGy), adjacent region
  2. Stray Low (20 cGy), more than one region away

Organ Dose Reconstruction Methodology

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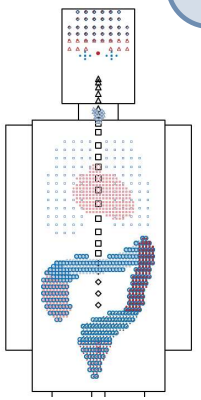
For EACH Individual in a Cohort

CCSS: N_{RT} > 13K

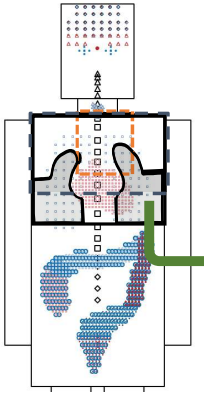
RT Record

Abstract Historic Record:
DOB, RT dates, Rx(s), field parameters + location

- In-house computational phantom scaled to individual's age at RT



- Create personalized reconstructed composite plan



Organ doses & dose-volume metrics

Dosimetry methods described in Howell et al. Radiat Res. **2019.** 192(2):169-188
Phantom and organ scaling described in Gupta *et al.* Biomed. Phys. Eng. Express. **2020** 6(6):2057-1976

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Organ Dosimetry Available for Overall Cohort

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Completed Organ/Region Dosimetry	Data Reported
Colorectum (whole, ascending, descending, transverse, rectum)	D_m, V_5, V_{10}, V_{20}, V_{30}
Heart (whole, aorta, arteries, valves, ventricles)	D_m, V_5, V_{20}
Ovaries (right and left)	D_m
Pancreas (whole, head, body, tail)	D_m V_{10}, V_{20}, V_{30}
Pituitary	D_m
Testes	D_m
Thyroid (right and left lobes)	D_m
Uterus	D_m
Breast (nipple/bud; underdeveloped; developed (whole, UIQ, UOQ, LIQ, LOQ, Central)	In Progress

- Mean dose (D_m)
- Dose-volume metrics: percent volume ≥ 5 Gy (V_5), ≥ 10 Gy (V_{10}), ≥ 20 Gy (V_{20}) and ≥ 30 Gy (V_{30})

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Contemporary Radiotherapy

Radiotherapy Evolution – Hodgkin Lymphoma

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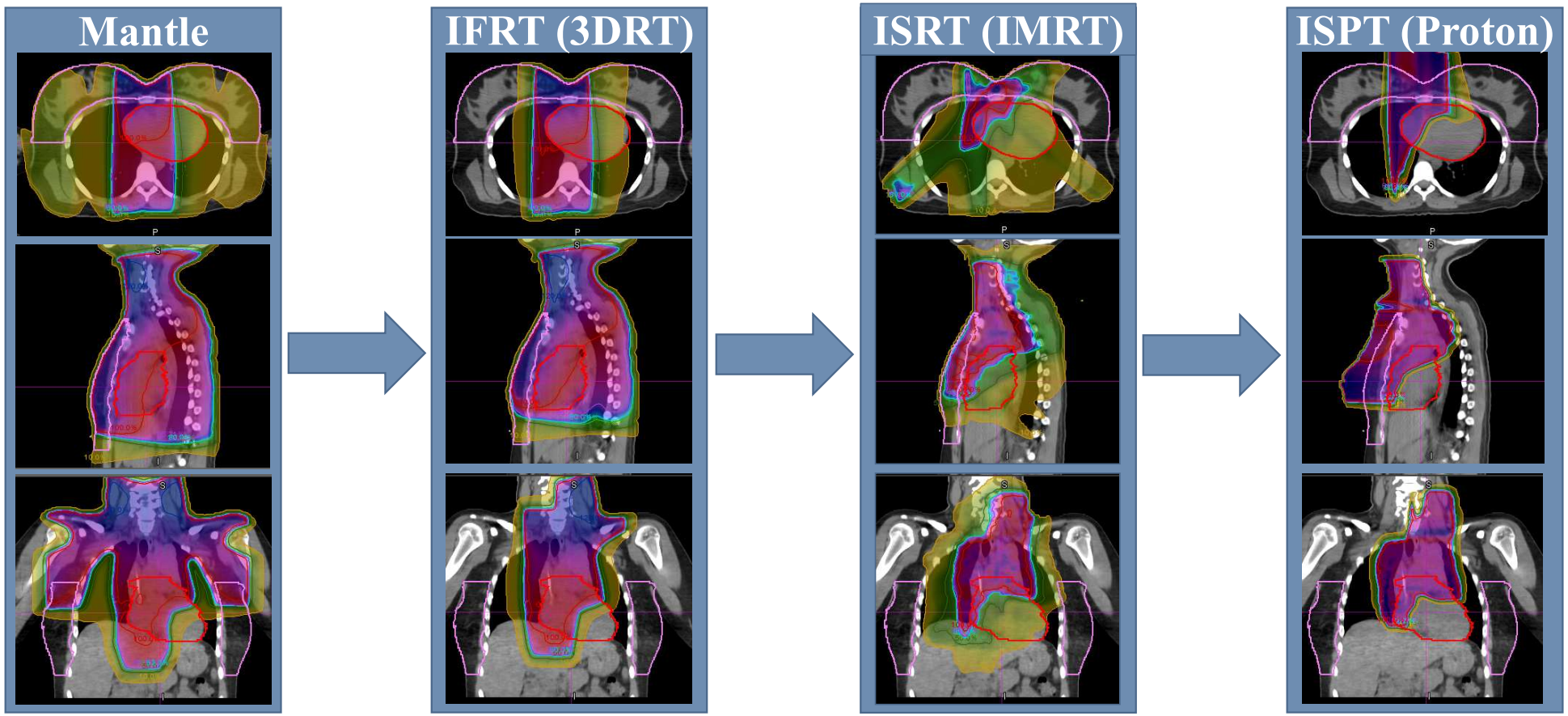

Slide adapted from Brad Hoppe, The Mayo Clinic – Jacksonville

Radiotherapy Evolution - Cranial Spinal Irradiation

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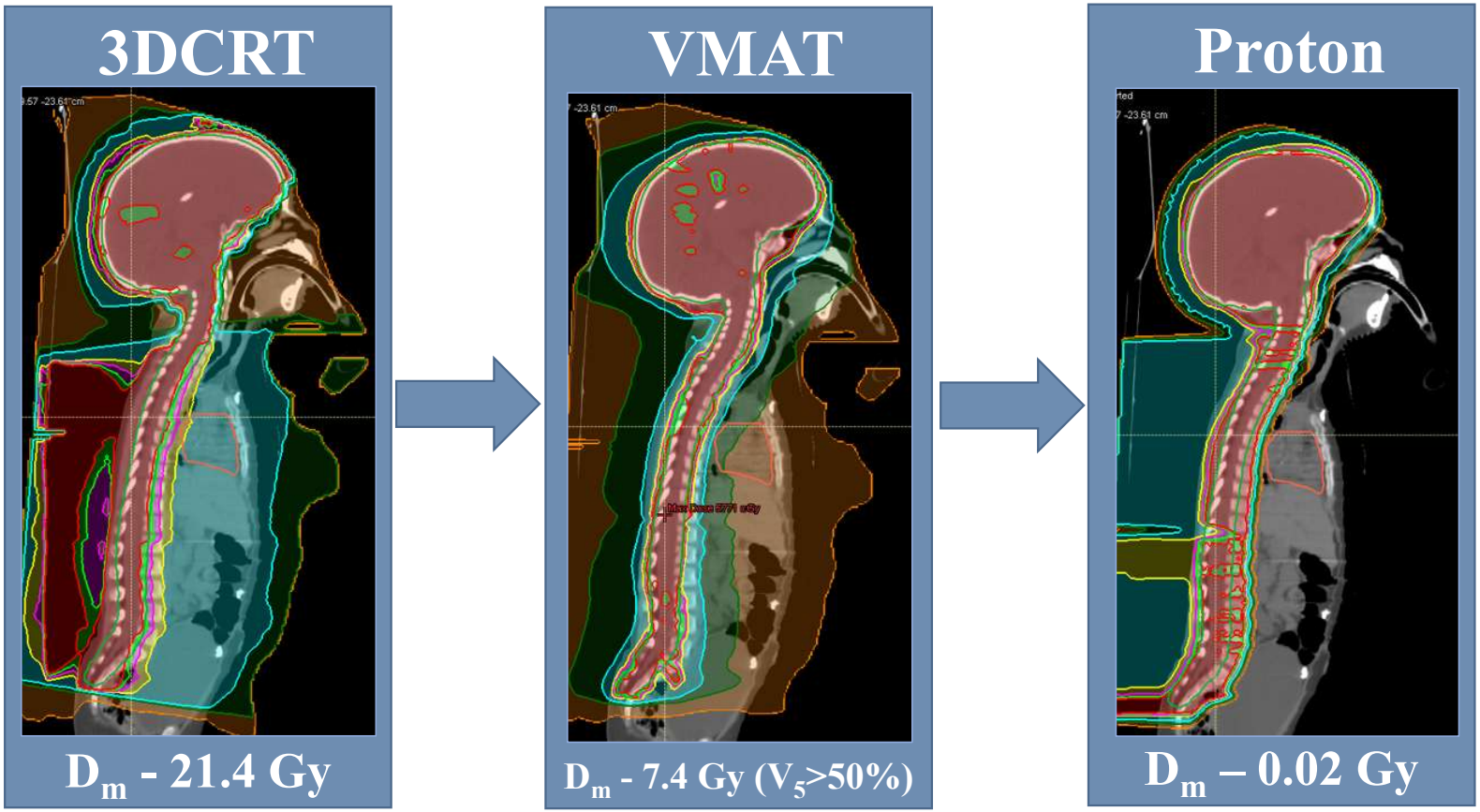

Slide adapted from Dan Indelicato, University of Florida

Contemporary RT Workflow

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Patients' treatment plan data are stored in **Digital Imaging and Communications in Medicine (DICOM)** format, which is a standard protocol for the management and transmission of medical images and related data.

New Dose Reconstruction Methods are Needed for Patients Treated with Contemporary RT

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CT Includes Anatomy Near RT Target

- Dose distributions are highly conformal
  - Organ doses need to be taken directly from individuals' RT plans and not reconstructed on surrogate anatomy
- However, not all organs of interest for late effects studies were contoured at RT

CT Does NOT include Distant Anatomy

- RT planning CT FOV is limited to anatomy near the treatment site, distant organs not in the FOV
  - Estimating dose to "out-of-FOV" organs requires replacing the missing anatomy with surrogate anatomy, e.g., computational phantoms

Reconstruction/Post Processing Required:

- Add contours for organs not segmented in CT at time of RT planning and update treatment plan so that dose is computed to new organ contours.

Dose Reconstruction Required:

- Fuse RT planning CT to age-scaled computational phantom, calculate doses to organs not in CT.

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Pilot Study
Cohort CCSS Millenium
Cohort Expansion

Pilot Cohort Objective

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Objective

- Pilot study to assess the feasibility of collecting multi-institutional, multi-modality contemporary radiotherapy data and generation of organ- and body region dosimetry for childhood cancer survivors treated between 2000 and 2022, and evaluation of comparability to existing Childhood Cancer Survivor Study (CCSS) dosimetry data (1970-1999)

Radiotherapy Pilot Study Workflow

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Five Pilot Study Centers

- Children's Hospital of Philadelphia
- Emory Winship Cancer Center
- MD Anderson Cancer Center
- Univ. Washington Seattle Children's Hospital
- St. Jude Children's Research Hospital

Each Center selects 6 patients/year treated with RT between 2000-2022 (age at RT < 21 years) and sends radiation therapy (RT) data to MDA

CCSS Radiation Physics Center at MD Anderson (MDA) Cancer Center

Process RT data to report mean doses and dose-volume metrics for in-field and out-of-field organs (whole body dosimetry)

CCSS Coordinating Center

Summary of Data Collected

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533 study participants from 5 centers

- ✓ Two sites collected DICOM data back to 2000 with the remaining three able to go back to 2008, 2009, 2010 (all confirmed that paper records were available for years in which DICOM data were not available)
- ✓ Body region dosimetry was completed for all study participants (N=533)
- ✓ Organ dosimetry was completed for 98% (522/533) study participants for whom DICOM were received
- ✓ For individuals for whom DICOM data were not available (2000-2009), paper records are available
  - *Estimate that 80-90% of treatments 2000-2008 were 2D and simple 3D and can be reconstructed with methods used for current CCSS*

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Contemporary RT Dose Reconstruction Methods Developed in the Pilot Study

Pediatric-trained Auto Segmentation Models

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Auto-segmentation Organ Models Developed as Part of Pilot Study			
Adrenal_L	Duodenum	Hippocampus_R	Pancreas
Adrenal_R	Esophagus	Heart	Parotid_L
Bladder	Eye_L	Kidney_L	Parotid_R
Brain	Eye_R	Kidney_R	Pituitary
BrachialPlex_L	Femur_Head_L	Lens_L	Prostate
BrachialPlex_R	Femur_Head_R	Lens_R	Rectum
Brainstem	Glnd_Lacrimal_L	Liver	SpinalCanal
Breast_L	Glnd_Lacrimal_R	Lung_L	SpinalCord
Breast_R	Glnd_Submand_L	Lung_R	Spleen
Carina	Glnd_Submand_R	OpticChiasm	Stomach
Cavity_Oral	Glnd_Thyroid	OpticChiasm	Thymus
Cochlea_L	Gonads	OpticNrv_L	UteroCervix
Cochlea_R	Hippocampus_L	OpticNrv_R	

- *Model validation and clinical assessment is in-progress*

Workflow to Create Organ Doses for Comprehensive Set of Organs (within CT FOV) for all Study Participants

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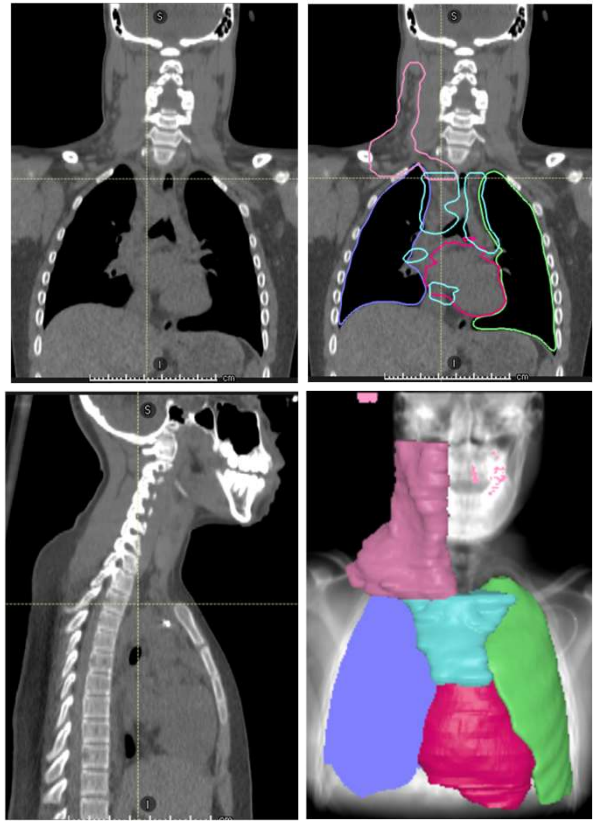
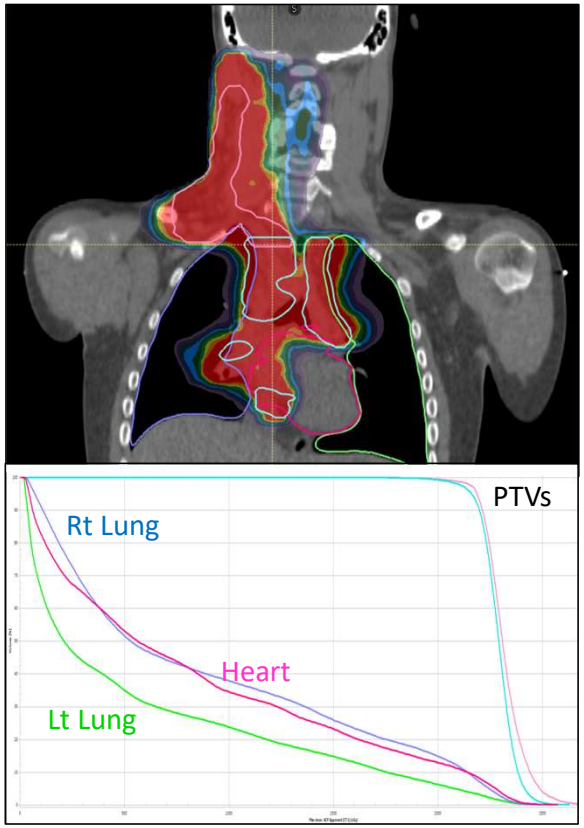
DICOM Data Collected for each Study Participant

RT Planning CT | **Structures** | **RT Plan and RT Dose**

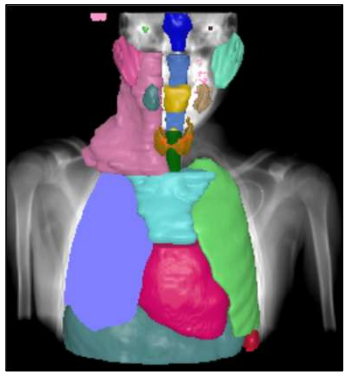


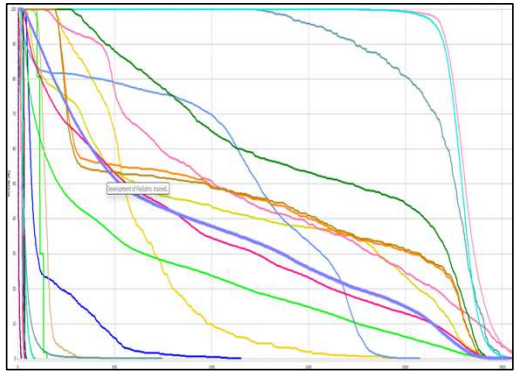


+ AI auto-Segmented Structures

Update dose grid to report dose for AI-segmented organs

Comprehensive Organ Dosimetry





- Pediatric-trained AI auto-segmentation models developed (validation is ongoing) as part of the CCSS Pilot Study would be used for Millenium cohort dosimetry

Workflow to Create Organ Doses for Comprehensive Set of Organs (not within CT FOV) for all Study Participants

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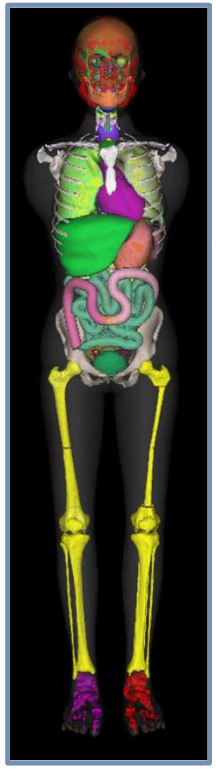
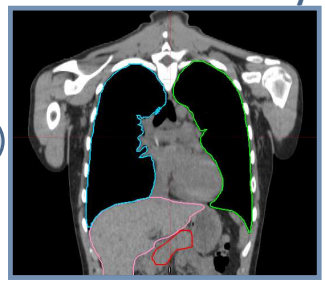
Deformable Image Registration & Dose Mapping

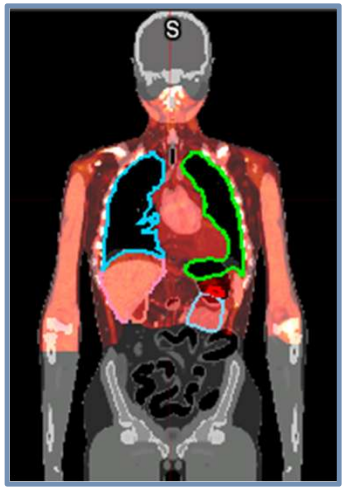
Age-Scaled Phantom



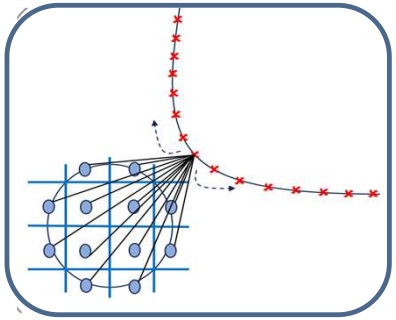
Patients' Partial-body CT



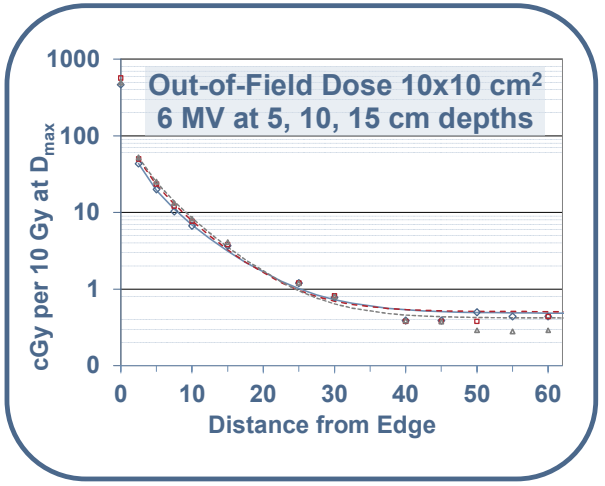
Registered CT



Estimate Patient's organ (not in CT FOV) doses using Phantom's Organs as Surrogates



- Measure distances from 50% isodose(field edge) to positions throughout phantoms' organs (only those not in the patient's CT).



- Apply out-of-field dose analytical modes to calculate dose to "missing" organs

CCSS Radiation Physics Center Summary

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- ✓ We are a resource for investigators from concept proposal development through analyses and manuscript writing
- ✓ We have reconstructed organ and body region doses for all survivors in the CCSS treated with radiotherapy; these dosimetry data are available to all CCSS investigators for their analyses
- ✓ In a recent pilot study, we collected multi-institutional, multi-modality contemporary radiotherapy data, completed dosimetry for study participants, and developed workflows for whole-body dosimetry for a future CCSS Millenium Cohort

Acknowledgements - Pilot Study Teams

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Children's Hospital of Pennsylvania/UPenn

- Christine Hill, MD
- Lea Dong, PhD

Seattle Children's Hospital/Univ. of Washington

- Ralph Ermoian, DO, PhD
- Eric Ford, PhD
- Sharareh Koufigar, MS
- Jie Fu, PhD

Emory Winship Cancer Center

- James Bates, MD

St. Jude Children's Research Hospital

- Thomas Merchant, MD
- John Lucas, MD
- Jared Becksfort
- Fang Xie

MD Anderson Cancer Center

- Radiation Physics Center Team
- Arnold Paulino, MD
- Peter Balter, PhD
- Tucker Netherton, PhD
- TJ Whitaker, PhD
- Christine Chung, CMD
- Meena Khan, CMD

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.

CCSS Website

Investigators interested in potential uses of this resource are encouraged to visit: http://ccss.stjude.org

All data also available on the St. Jude Cloud Survivorship Portal:

- >30,000 survivors (CCSS + SJLIFE cohorts)
- Treatment, outcomes and genetic data
- survivorship.stjude.cloud

Survivorship Portal


Thank You

Contemporary RT Workflow

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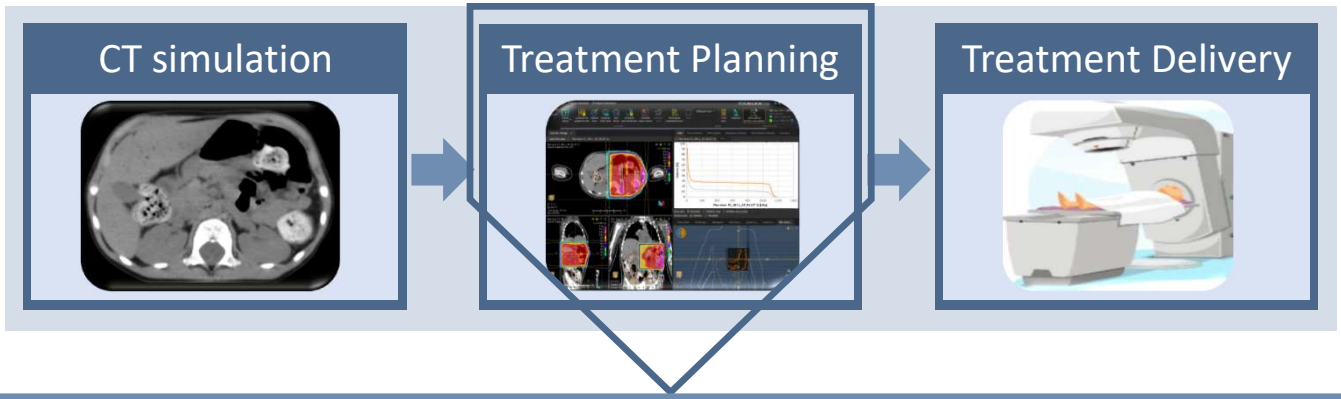

Patients' treatment plan data are stored in **Digital Imaging and Communications in Medicine (DICOM)** format, which is a standard protocol for the management and transmission of medical images and related data.

DICOM is the international standard to communicate and manage medical images and data. Its mission is to ensure the interoperability of systems used to produce, store, share, display, send, query, process, retrieve and print medical images.

and set of patient structures.

4. **RT Dose:** Contains dose data generated by a treatment planning system in one or more of several formats:

RT dose-volume metrics

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Breast Dose-volume histogram (DVH):

- Relate RT dose to volume of whole breast and breast subregions

Breast DVH Illustrations:

- In-field (UOQ)
- Partially-blocked (UIQ)
- Blocked (LOQ)

Dose-volume metrics:

- V_x is the % volume receiving ≥ X Gy
- V_{20} (% of volume that received ≥ 20 Gy):
  - UOQ = 42.30%
  - UIQ = 20.05%
  - LOQ = 0.00%

Slide from Taylor Meyers