

# **Update from the Radiation Physics Center**

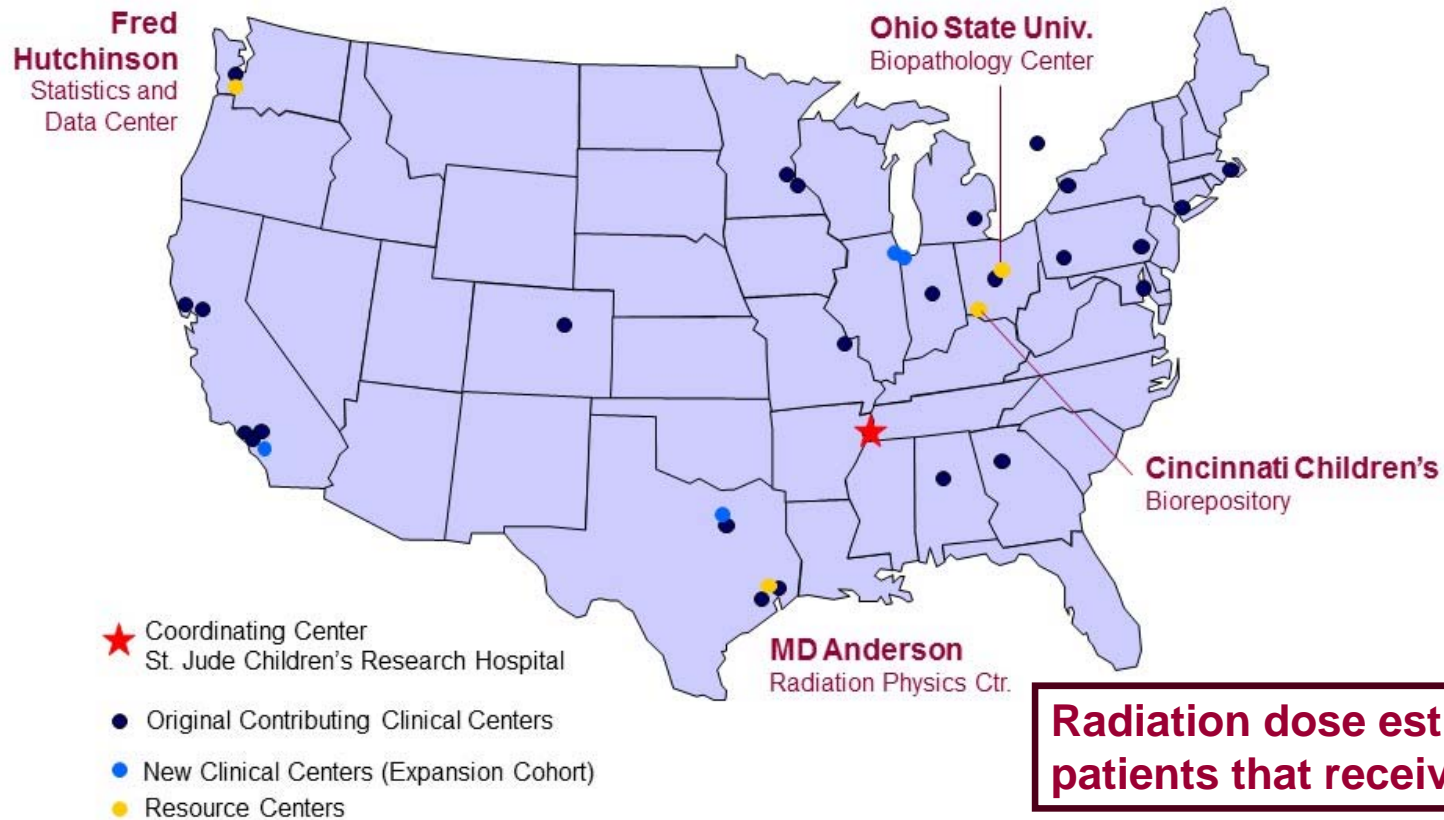
## **A Report from the Childhood Cancer Survivor Study**

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Tera Jones, Samantha Murray, and Debbie Tanner



Department of Radiation Physics

# Collaborating Institutions and Resource Centers



## The Role(s) of the Radiation Physics Center

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

# Progress Update

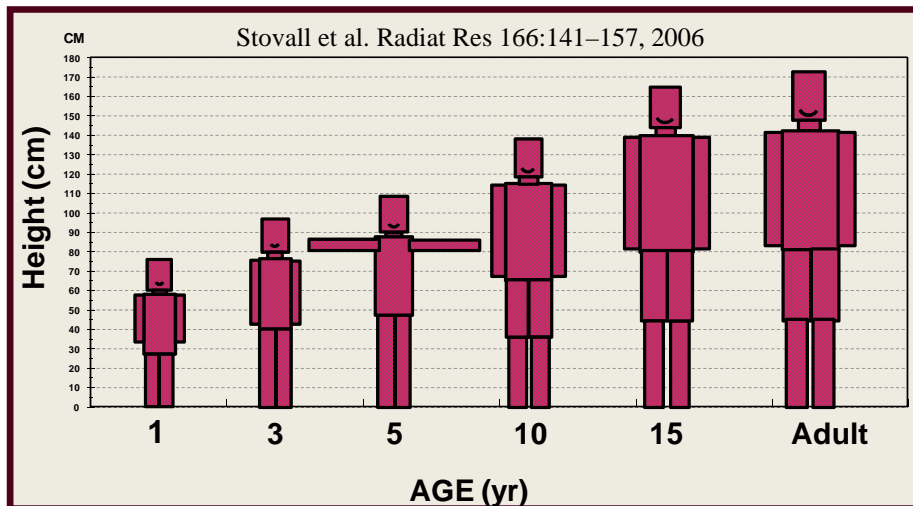
## Since the October 2016 Executive Committee Meeting

- Completed Dosimetry
  - Heart including dose volume data
  - Ovaries (minimum and maximum dose, proximity to the treatment field)
  - Updated body region dosimetry for additional patients
- Dosimerty in-progress
  - Pituitary (estimated 07/2017)
  - Detailed field data and corresponding prescribed dose (estimated 08/2017)

# **Mathematical Phantoms used for Radiation Dosimetry**

## Age Specific Phantoms

- Master (generic) phantom is scaled (linear interpolation) to age at RT
  - To allow for uneven growth rates for the different age groups, we apply different scaling factors for the phantom head, trunk and limbs.

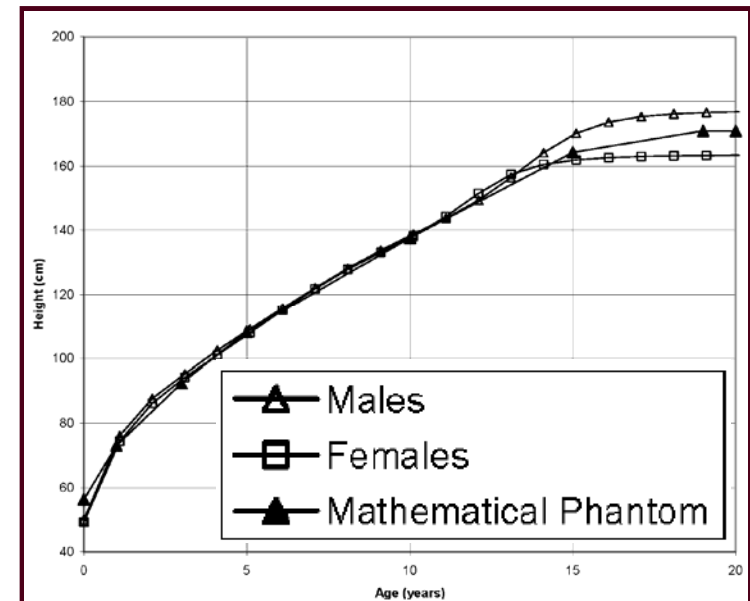


Why don't we scale  
according to BMI?

BMI is rarely in the RT record!

## Age Specific Phantoms

- How were body sizes defined?
  - Based on data from a study of body dimensions of > 4000 U.S. children (conducted by the National Safety Council Society of Automotive Engineers).
- How were body sizes validated?
  - By comparison of phantom heights and CDC growth chart data



# **The Radiation Dosimetry Process**



# Radiation Dosimetry Process

1. Abstract patients' RT record
2. Reconstruct RT fields on age-specific phantoms
3. Calculate dose to regions and organs of interest
4. Quality assurance of computed doses
5. Create output files and documentation
6. Provide data to FH Statistics Center for distribution of data to individual investigators.

# Record Abstraction

- Pertinent data
  - Treatment Dates
  - Date of Birth
  - Prescription(s)
  - Field Data: orientation, energy, weighting, blocking, modifiers, borders etc.
- Record length varies
  - 1 to >250 pages
- Coding time varies
  - 20 min to 2 hrs
- No direct correlation between record length and quality.

**CCSS II - Radiation Therapy - Ver. 4** designed 11/25/08 - mod 9/18/09 - mod 6/21/10 - mod 9/13/10

DOB (mm/dd/yyyy):  /  /  page  of  CCSS ID:  -  -

**Reason**  
 Primary/Recurrence = 1  
 Metastatic disease = 3  
 Second Cancer (SMN) = 2  
 Other = 8     Unknown = 9

**Dates of Therapy**  
 Begin Date (mm/dd/yyyy)  /  /   
 End Date (mm/dd/yyyy)  /  /

**Special Technique**  
 SRS (1)     None (0)  
 IMRT (2)  
 Other (8) \_\_\_\_\_

**Beam Type:**  
 Co60 (02)  
 Cs137 (03)  
 Photons (04)  
     MV:  /   
 Electrons (07)  
     MeV:  /   
 Ortho (01)  
     KVP:  /   
     HVL (mm)  /   
 AL  CU  Unk  
 Betatron (05)  
     MV:  /   
 Brachy/Nuclear Scans (77)  
 Other (88) (Note in Comment)  
 Unknown (99)

**Comments:**  Yes     No

**Field**  
 MANTLE (330):  
 T-Shaped (221)  
 ABDOMEN [not kidney] (400):  
 Para-Aortic (410)  
     Spleen/Pedicle Treated:  
 Yes     No     UNK  
     Liver Treated:  
 Yes     No     UNK  
 KIDNEY (401)  
 ABDOMEN & PELVIS (700):  
 Whole (706)  
 Inv. Y (710)  
 Dogleg (730)  
 Spade (720)  
     Spleen/Pedicle Treated:  
 Yes     No     UNK  
     Liver Treated:  
 Yes     No     UNK  
 PELVIS (500):  
 V Pelvis (520)  
 Inguinal (530)  
 Testicular (540)  
 Perineal (550)  
 OTHER (888)    Body Site  /  /

**Field Top/Bottom Borders**  
 Top:    Bottom:  
 Top of Head      (00)  
 Ear/Jaw      (01)  
 Mid neck      (02)  
 SSN      (03)  
 Mid chest      (04)  
 Nipple      (05)  
 Diaphragm      (06)  
 L2      (12)  
 Umbilicus      (07)  
 L5      (08)  
 L5/S1 Junction      (14)  
 Mid pelvis      (09)  
 Top of Femur      (13)  
 Pelvic Floor      (10)  
 Upper Leg      (11)  
 Other      (88)  
 /  /      /  /   
 Unk      (99)  
 N/A      (77) ==>

If N/A (77) is chosen answer the default center question below - code a center if no is marked  
 ==> **Default Center:**  
 Yes     No

X  /  /     Y  /  /     Z  /  /

**Field Proximity**  
 To Midline (1)     Over Midline (2)     Unk (9)  
 Whole (3)     NOT to Midline (4)

**Size (mm) : (w x h)**  
 X

**Any Blocking?**  
 No (0)     Unk (9)  
 Yes (1)

**Field Wedged?**  
 No  
 Yes  
 - Wedge Angle:  /

**Laterality**  
 Right (1)  
 Left (2)  
 Rt & Lt (3)  
 Central (4)  
 Unk (9)

**Config**  
 A & P (01)     Lat(s) (04)     Inf & Sup (07)  
 A & P Oblique (12)     Lat Oblique Pair (64)     Inferior (17)  
 A only (02)     Lat Oblique One (65)     Superior (27)  
 Ant Oblique (62)     Tang (06)     Other (88) (Note in comment)  
 P only (03)     Direct (10)  
 Post Oblique (63)     Arc/Rotational (11)     Unk (99)

**Dose**  
 /   
**Dose Def:**  
 Tumor (3)    If Tumor dose code depth.  
 Given (2)    Depth (cm)  /   
 Air (1)  
 Other (8)  
 Gy (3)     Unk (9)  
 Roentgen (4)

| Field Proximity     | Sex: <input type="checkbox"/> MALE <input type="checkbox"/> FEMALE <input type="checkbox"/> UNK | Testes Shield / Pinned Ovary (5)         | TE Shld Moved & Blk Away (7)          | UNK (6)                                    | Review (R)                               |  |
|---------------------|---|--|---------------------------------------|--|--|--|
| <b>Pituitary:</b>   | Out > 3cm (0) <input type="checkbox"/> (0)  | In Beam (1) <input type="checkbox"/> (1) | Edge (2) <input type="checkbox"/> (2) | Near <3cm (3) <input type="checkbox"/> (3) | Blocked (4) <input type="checkbox"/> (4) | <input type="checkbox"/> (9) <input type="checkbox"/> (R)  |
| <b>Thyroid:</b>     | <input type="checkbox"/> (0)  | <input type="checkbox"/> (1)             | <input type="checkbox"/> (2)          | <input type="checkbox"/> (3)               | <input type="checkbox"/> (4)             | <input type="checkbox"/> (9) <input type="checkbox"/> (R)  |
| <b>Heart:</b>       | <input type="checkbox"/> (0)  | <input type="checkbox"/> (1)             | <input type="checkbox"/> (2)          | <input type="checkbox"/> (3)               | <input type="checkbox"/> (4)             | <input type="checkbox"/> (9) <input type="checkbox"/> (R)  |
| <b>Testes:</b>      | <input type="checkbox"/> (0)  | <input type="checkbox"/> (1)             | <input type="checkbox"/> (2)          | <input type="checkbox"/> (3)               | <input type="checkbox"/> (4)             | <input type="checkbox"/> (5) <input type="checkbox"/> (7) <input type="checkbox"/> (6) <input type="checkbox"/> (9) <input type="checkbox"/> (R) |
| <b>Left Ovary:</b>  | <input type="checkbox"/> (0)  | <input type="checkbox"/> (1)             | <input type="checkbox"/> (2)          | <input type="checkbox"/> (3)               | <input type="checkbox"/> (4)             | <input type="checkbox"/> (5) <input type="checkbox"/> (9) <input type="checkbox"/> (R)   |
| <b>Right Ovary:</b> | <input type="checkbox"/> (0)  | <input type="checkbox"/> (1)             | <input type="checkbox"/> (2)          | <input type="checkbox"/> (3)               | <input type="checkbox"/> (4)             | <input type="checkbox"/> (5) <input type="checkbox"/> (9) <input type="checkbox"/> (R)   |
| <b>Uterus:</b>      | <input type="checkbox"/> (0)  | <input type="checkbox"/> (1)             | <input type="checkbox"/> (2)          | <input type="checkbox"/> (3)               | <input type="checkbox"/> (4)             | <input type="checkbox"/> (9) <input type="checkbox"/> (R)  |

**Information Received:**  
 Complete record (1)  
 Partial record (2)  
 Notes &/or Summary (3)  
 Abstract information only (4)

**Quality Score:**  
 Good (1)  
 Item(s) missing/not important (2)  
 Item(s) missing/important (3)  
 Inadequate for dosimetry (4)  
 Part inadequate (5)

**Sim Film Available:**  
 yes     no

**Photo Available:**  
 yes     no

**Diagram:**  
 yes     no

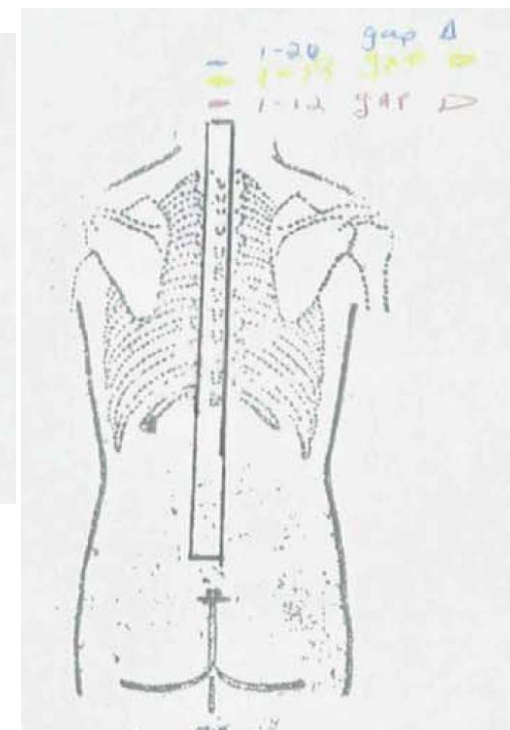
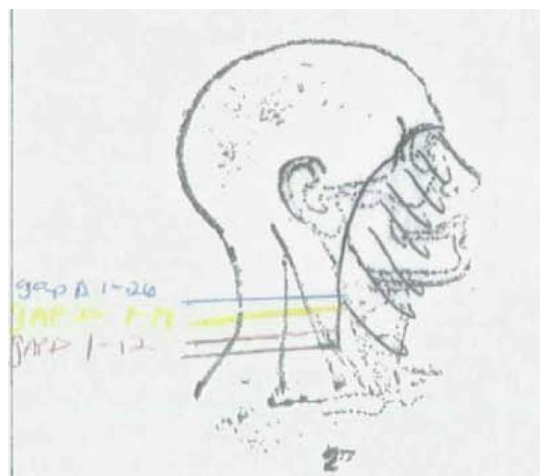
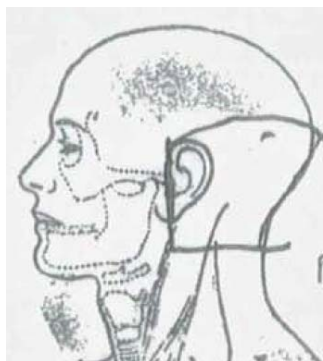
Abstracted By:  on  /  /  /  /  /  Minutes to abstract:  /  /

QC By:  on  /  /  /  /  /  Minutes required to QC:  /  /

3051241488

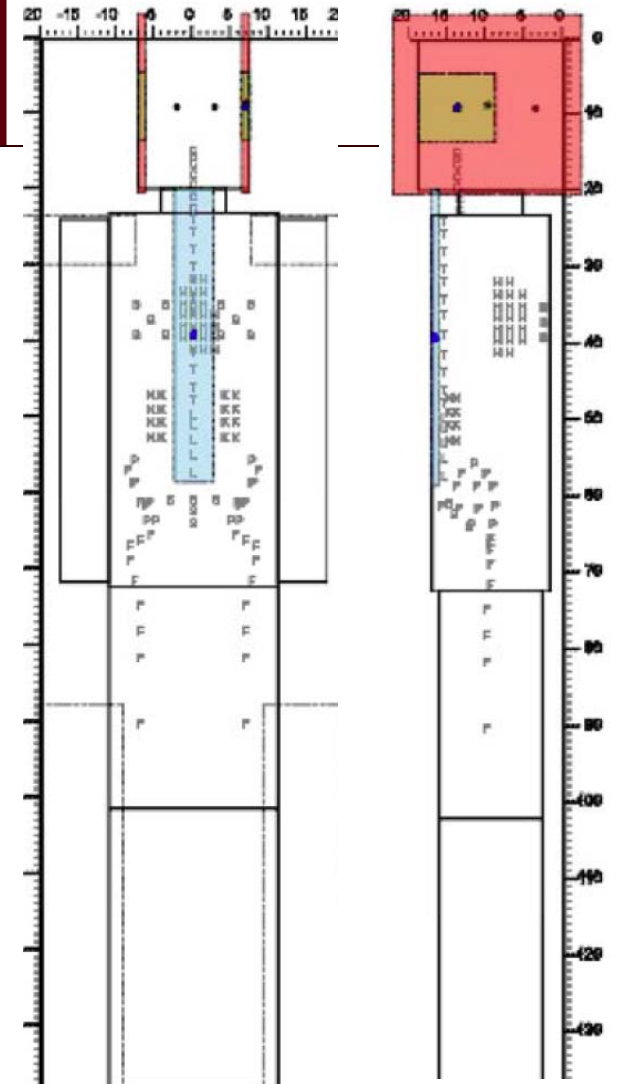
# Field Placement Cranial Spinal Record Example

- Initial Fields (6 MV)
  - Right and left lateral brain fields top of head to C6
  - Posterior spine field C6 to L5/S1 junction
- Posterior Fossa Boost (6 MV)



# Field Placement Cranial Spinal Record Example

- Coded fields are placed on an *age-specific* mathematical phantom based on abstracted data.
  - Note “eye and face” blocking not shown in the rendering, but included for dosimetry calculations.
- Dose calculated for each field and can be determined for any point (x,y,z) within phantom’s 3D grid.



# Levels of Radiation Dosimetry

# Different Levels of Radiation Dosimetry

- **Study Specific Dosimetry Tiers**

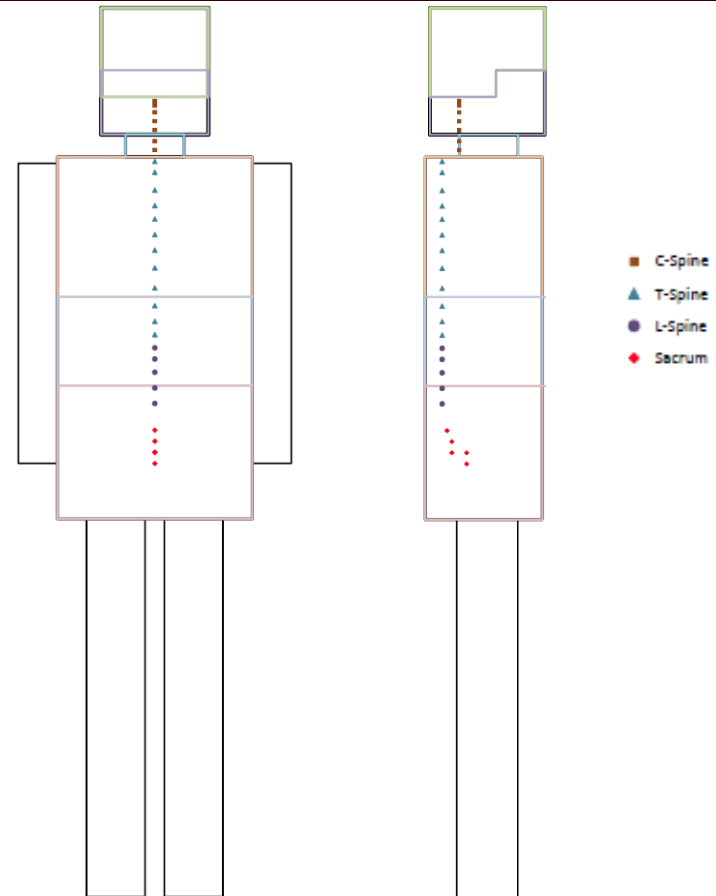
- Y/N RT ( per FH stats/data center)
- Y/N for specific types of RT, e.g., CSI, TBI, etc.
- Body region maximum tumor dose (maxTD)
- Organ specific doses, e.g., heart, thyroid, gonads, pancreas, etc.
- Average dose (most common parameter)
- Average dose to organ parts, e.g., pancreas head, body, tail
- Percent volume that received  $\geq X$  Gy, e.g.,  $PV_5$ ,  $PV_{10}$ ,  $PV_{20}$

M  
D  
A

# Phantom Body Regions

- Body Regions

- brain
- other head
- neck
- chest
- abdomen
- pelvis
- extremities



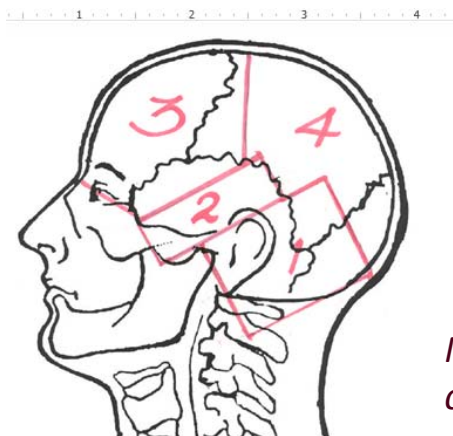
# Body Region Dosimetry

- In-beam Region
  - Maximum treatment dose (MaxTD) to specific body regions taking into account only direct in-beam contributions to that region.
- Two Out-of-beam Regions based on distance from in-beam region
  - Stray High (SH) Region
    - Adjacent to an in-beam region
    - Doses are 1% to 10% of maxTD
  - Stray Low (SL) Region
    - Not Adjacent to an in-beam region
    - Doses <1% of maxTD



## Body Region Dosimetry Example

- Patient received 36 Gy whole brain RT with an 18 Gy posterior fossa boost
  - In-beam
    - Brain Region maxTD = 54 Gy
    - Brain 4 segments
      - Regions 3 and 4 maxTD = 36
      - Regions 1 and 2 maxTD = 54
  - Out-of-beam Regions
    - Neck = SH
    - Chest = SL



*Note if  $\geq 50\%$  is covered, considered "treated".*

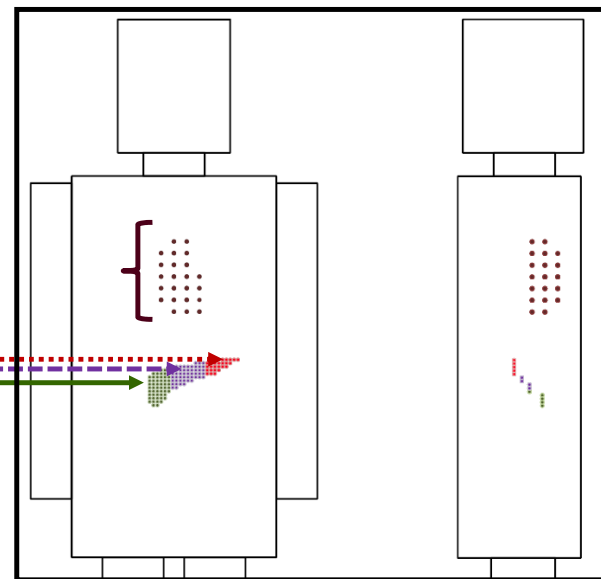
# Organ Dosimetry

- Organs represented by a grid of points (x,y,z).
  - Grid can be moved.
  - Grid resolution can be  $\uparrow$  or  $\downarrow$ .
- Organ positions
  - Defined based on bony anatomy, proximity to other organs, etc.
  - Peer reviewed by study investigators.

Average organ dose can be computed  
for an entire organ  
or individual parts of an organ

## Example Organs

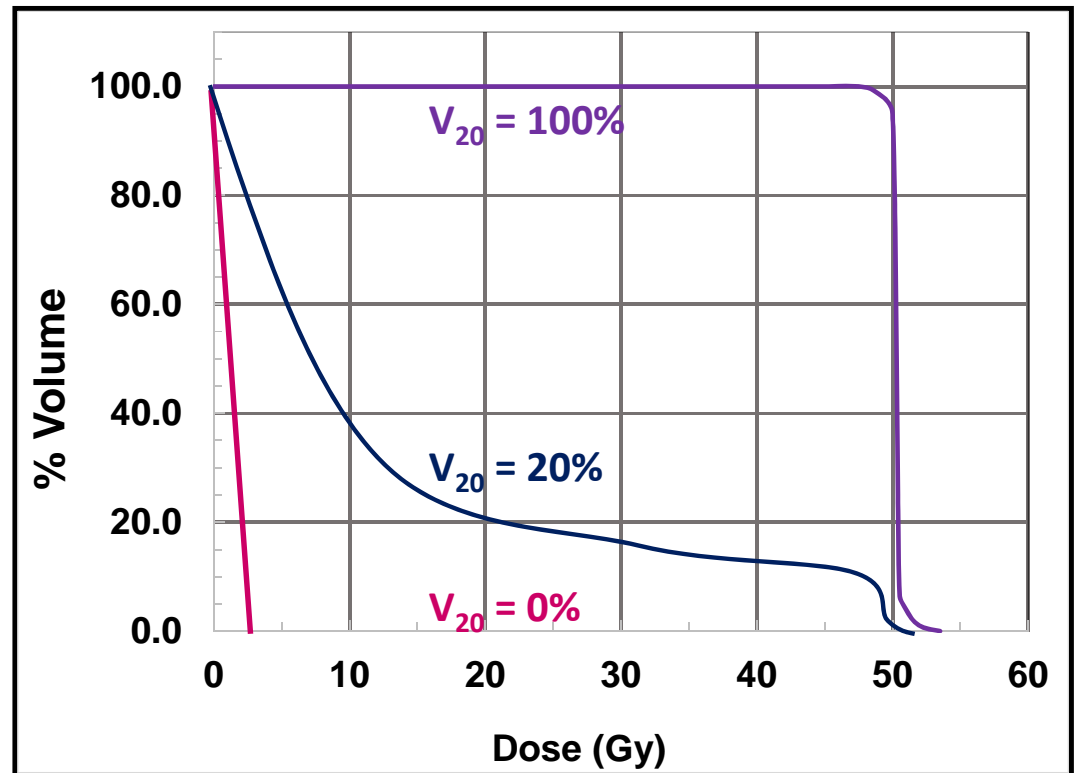
- Heart: 55 points
- Pancreas: 129 points  
54 head, 50 body, 25 tail



# Dose Volume Metrics

- Dose Volume Histogram: plot % volume receiving  $\geq$  dose levels.
- Useful metric: percent volume receiving  $\geq$  a dose of interest.

*Example: What percentage of the organs' volume received  $\geq$  20 Gy ( $V_{20}$ )?*



# Dose Volume Metrics – Recent Developments

- Because dose is calculated for each point within an organ and points within an organ are evenly spaced within a 3D grid → the percent of points in an organ that receive  $\geq$  “x” dose can be used to represent  $V_x$ .

*We recently calculated  $V_x$  data for heart and pancreas for overall cohort (13649 patients).*

| Proposal# | Concept Title  | Lead Author | Approval Year | Citation | Working Group                               |
|-----------|--|-------------|---------------|----------|---|
| 16-07     | The Impact of Developmental Status on Radiation-associated Late Cardiac Toxicities in Long-Term Survivors of Childhood Cancer. | James Bates | 2016          |          | Chronic Disease, Epidemiology/Biostatistics |

Average,  $V_5$ ,  $V_{10}$ ,  $V_{15}$ ,  $V_{20}$

| Proposal# | Concept Title   | Lead Author                | Approval Year | Citation | Working Group   |
|-----------|---|----------------------------|---------------|----------|-----------------|
| 15-08     | Impact of Radiation Dose and Volume to the Pancreas on Subsequent Risk of Diabetes Mellitus in Long-term Survivors of Childhood Cancer Treated with Abdominal Radiation: A Report from the Childhood Cancer Survivor Study. | Danielle Novetsky Friedman | 2015          |          | Chronic Disease |

Average dose for whole, head, body, tail and  $V_{20}$  and  $V_{30}$  for whole pancreas

# Completed Cohort Dosimetry to Date

| Organ/Region                      | Data Reported  | Cohort                          |
|-----------------------------------|--|---------------------------------|
| Body Regions + brain 4 seg        | MaxTD, SH, SL  | Overall                         |
| Eyes/lenses                       | Average Dose   | Original                        |
| Heart                             | Average dose, $V_5$ , $V_{10}$ , $V_{15}$ , $V_{20}$                                 | Overall                         |
| Lungs                             | Average dose   | Overall (*12,846 patients)      |
| Ovaries                           | Average dose   | Overall (female)                |
| Uterus                            | Average dose   | Overall (female)                |
| Pancreas                          | Average dose for whole, head, body, tail<br>$V_{20}$ and $V_{30}$ for whole pancreas | Overall                         |
| Pituitary                         | Average dose   | Original, Expansion (est. 6/17) |
| Salivary Glands                   | Average dose   | Original                        |
| Spleen (Abdomen LUQ as surrogate) | Average dose   | Overall                         |
| Testes                            | Average dose   | Original                        |
| Thyroid                           | Average dose   | Original                        |
| Teeth                             | Average dose   | Original                        |

# Acknowledgements

- Susan Smith
- Jacob Palmer
- Irene Harris
- Rita Weathers
- Tera Jones
- Samantha Murray
- Debbie Tanner



# Childhood Cancer Survivor Study

- 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>