# Radiation & Radiology (R&R)

NAACCR 2023-2024 Monthly Webinar Series

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## Q&A

Please submit all questions concerning the webinar content through the Q&A panel.

If you have participants watching this webinar at your site, please collect their names and emails.

We will be distributing a Q&A document in about one week. This document will fully answer questions asked during the webinar and will contain any corrections that we may discover after the webinar.

2

# Fabulous Prizes


3

# Guest Presenters

- Jared D. Christensen, MD, MBA
- Wilson Apollo, MS, C.T.R.

4

# Radiology

Jared D. Christensen, MD, MBA

## Agenda

- ACR RADS
- Lung
- Technical Questions

Dr Jared Christensen, MD, MBA

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## ACR RADS and Reportability

STORE 2024

- PI Rads, BI Rads, LI Rads alone are not reportable for CoC.
- PI Rads, BI Rads, LI Rads confirmed with biopsy or physician statement are reportable to CoC.
- Date of diagnosis is the date of the positive biopsy.

SEER

Diagnostic

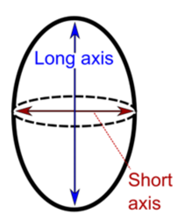
- Liver cases with an LI-RADS category LR-4 or LR-5
- Prostate cancer cases with an PI-RADS category 4 or 5

Not Diagnostic

- Bi RADS

## Lung Specific Questions

- Intrapulmonary metastasis vs synchronous tumors
- Ground glass opacities
- Lymphadenopathy
- Smoking/histology

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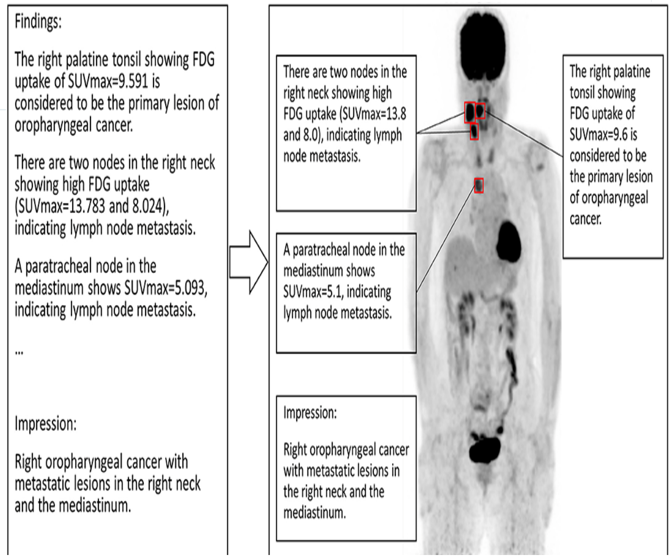
# Technical Questions

- PET and PET/CT
  - Fluorodeoxyglucose (FDG)
    - Radioactive atom is applied to glucose (blood sugar) to create a radionuclide called fluorodeoxyglucose (FDG)
  - Standardized Uptake Values (SUVs)
    - Refers to the ratio of the concentration of radiopharmaceutical (usually FDG) in a volume of tissue
  - Contraindication

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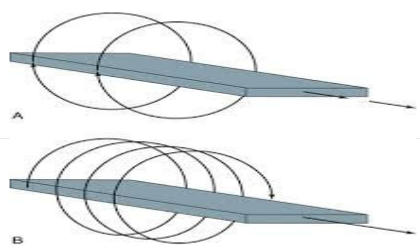
# Technical Questions




- CT Scan
  - Axial vs Helical
  - Pitch
  - Indication for contrast
- MRI
  - T1 MRI
    - Highlights anatomy, provides clear images, and shows fluids as dark. T1-weighted images also show "black holes," which are thought to indicate areas of permanent damage.
  - T2 MRI
    - Focuses on pathology, making fluids bright, which is ideal for visualizing inflammation, edema, and certain lesions.
    - T2-weighted MRI scans are used to provide information about disease burden or lesion load or the total amount of lesion area.

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# Radiation

Wilson Apollo, MS, CTR

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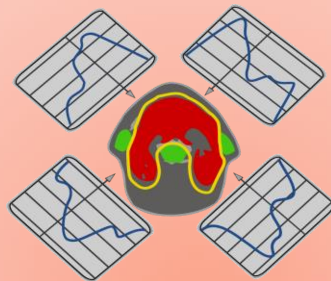


# The Role of Imaging in Radiation Therapy Planning & Delivery

Wilson Apollo, MS, CTR, RTT
WHA Consulting

NAACCR

December 14, 2023



2

## Goal of Radiation Therapy

- “Deliver the maximum allowable tumoricidal dose to the primary tumor volume while minimizing dose to organs at risk/healthy tissue”

3

## Goal of Radiation Therapy- Considerations

a. What is the tumoricidal dose for site(s) in question?
b. What are the organs at risk in the vicinity of the targeted site and what are the radiosensitivity of these organs?
c. What are the dose constraints for organs at risk?
d. How well can we delineate the target site and organs at risk during treatment planning/treatment?
e. How can we compensate for anatomical changes to the tumor during treatment?

4

## Goal of Radiation Therapy- Considerations

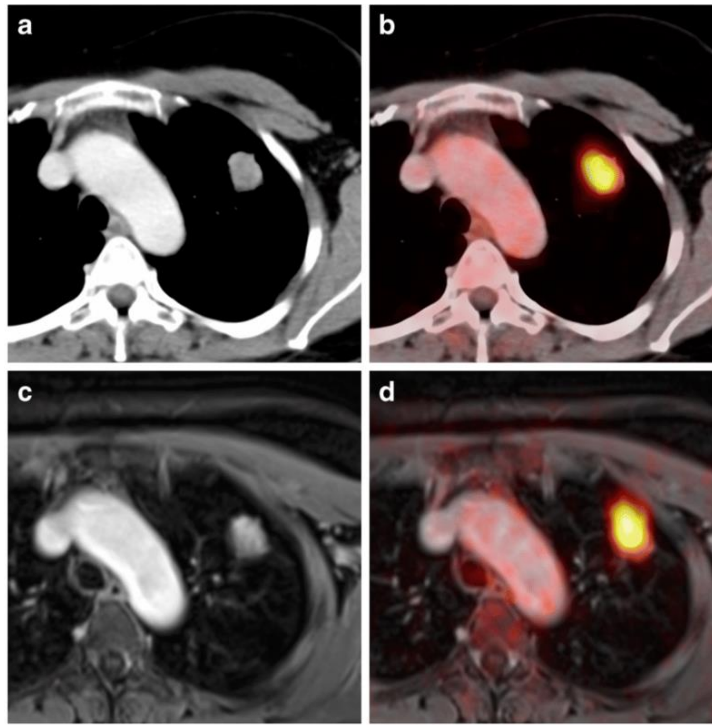
1. **Tumor Control Probability** (TCP) model: it quantifies the probability that a tumor is controlled (stop growth and cause tumor necrosis),
2. **Normal Tissue Control Probability** (NTCP) model: quantifies the probability that normal tissues around target tumor (OARs) are not harmed.

Impossible to administer curative doses to target volume without depositing a portion of the dose to OARs!

5

# LUL Lung Cancer

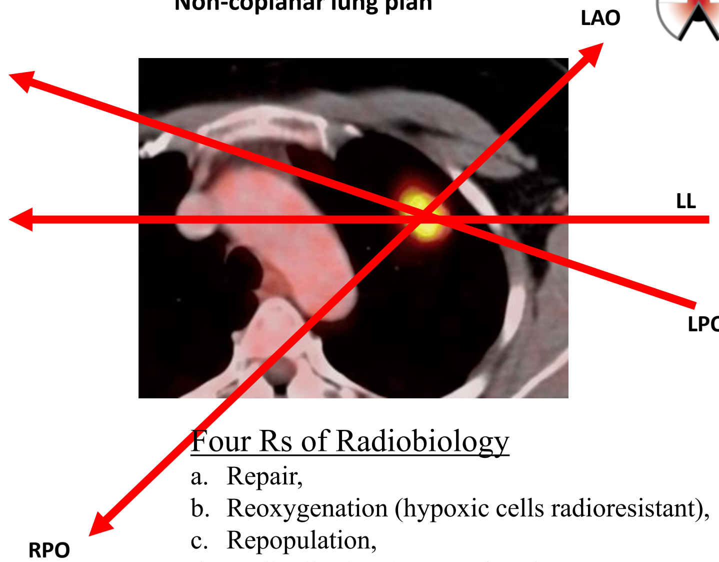
- 22 mm on MRI (c),
- 24 mm on CT (a),
- b: PET/CT fused images
- d: MRI/PET fused images,
- Consider location of tumor relative to adjacent critical structures, such as
  a. Contralateral lung,
  b. Esophagus,
  c. Trachea,
  d. Heart,
  e. Spinal cord




6

| Organs @ Risk | Dmax |
|---|---|
| Contralateral lung | 30-40 Gy |
| Heart | 30-40 Gy |
| Esophagus | <69 Gy |
| Trachea | 30 Gy |
| Brachial plexus | <54 Gy |
| Spinal cord | ≤ 45 Gy |

**Non-coplanar lung plan**




<u>Four Rs of Radiobiology</u>

a. Repair,
b. Reoxygenation (hypoxic cells radioresistant),
c. Repopulation,
d. Redistribution (Late G2/M phase most radiosensitive. S phase radioresistant.
e. Radiosensitivity ($5^{th}$ R)

7

# Standard fractionation vs. hypofractionation

- Question remains on how the four(five)Rs of radiobiology react to different fractionation schedules, standard vs. hypofractionation,
- For prostate cancer, studies support use of hypofractionation/SBRT,
- SBRT standard of care for inoperable early-stage NSCLC; option also for recurrent disease,
- Given complexity of RT planning and delivery,
  - Important to maximize precision of RT delivery,
  - Critical to use imaging technology to accurately delineate target volume and track its changes as treatment progresses,
  - Adapt to changes in target volume in a reasonable time frame.

8

# In my beginning…1999
# Simulation specialist

- Varian Ximatron C simulator,
- Use of fluoroscopy unit for initial patient set up,
- Used imaging cassette,
- Required a dark room for processing,
- Extensive use of bony anatomy for set up purposes,
- Permanent “tattoos” marked on pts.

9

# In my beginning…1999 Simulation specialist

- Use of Cerrobend (Lipowitz) blocks to conform to target volume,
- Cerrobend alloy consists of 50% Bismuth, 26.7% Lead, 13.3% Tin & 10% Cadmium,
- Custom made for each patient,
- Low melting point; reusable,
- Attached to holding tray on gantry component of Linac,

10

# Today…

- Modern, efficient, fast CT-based simulators
- Set up based on actual target anatomy and critical structure contouring

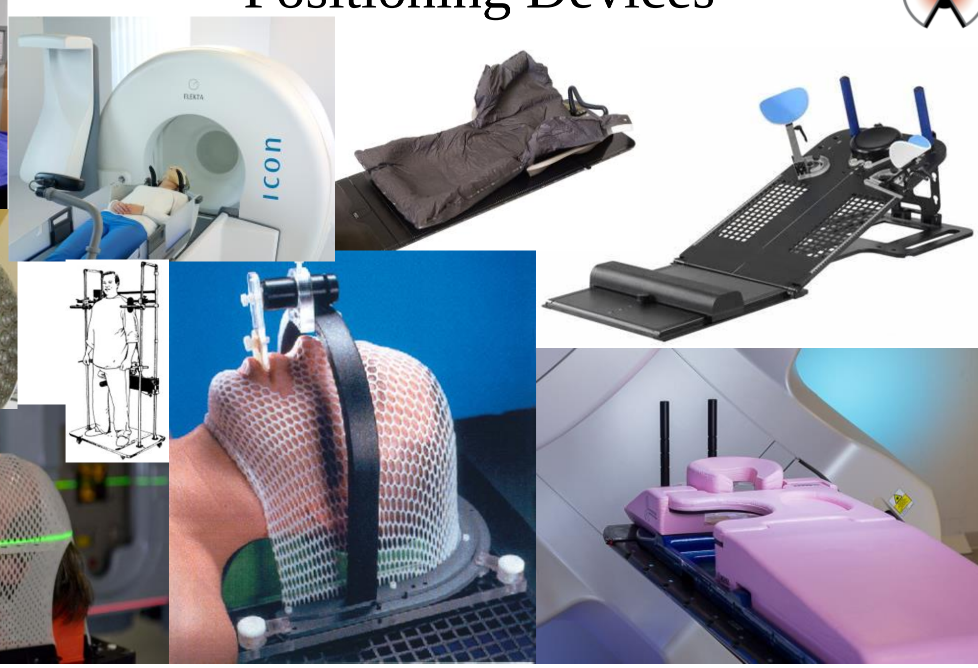
11

# RT Simulation Process-Patient

- Pt “simulated” on actual reproducible treatment position; positioning devices considered, depending on site treated,
- Depending on site treated, pt may have IV contrast administered prior to CT scan; if on full bladder protocol, pt will have to drink a specified volume of water; if on DIBH protocol, breath hold training performed,
- Removable markers placed on pt’s skin to assist with pt positioning on couch for treatment,
- CT scan is performed; procedure is quick. Pt is given appt for 1st treatment; depending on complexity of plan, it could take a week or two from date of simulation.

12

# Positioning Devices

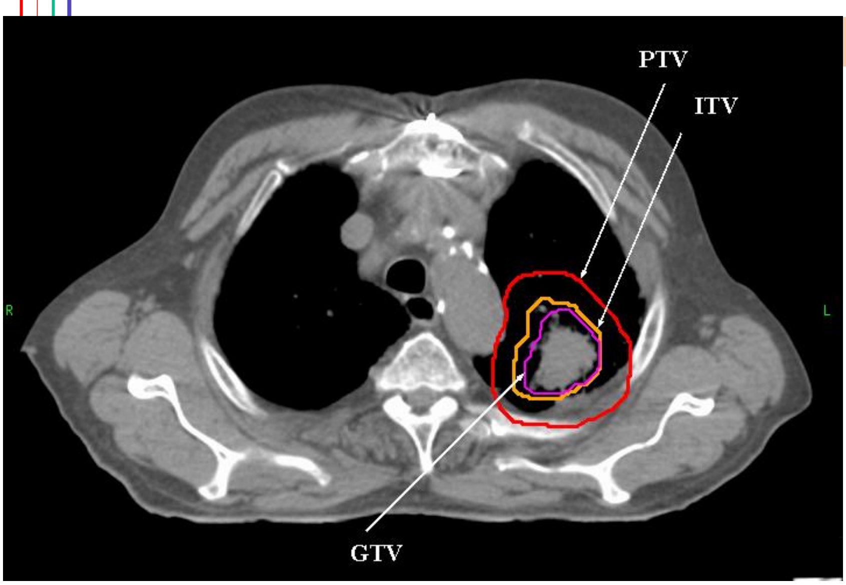

13

# RT Simulation Process-Treatment Planning

- CT images acquired during the simulation (sim) process are imported to treatment planning system; diagnostic images can be merged w/ sim CT,
- Primary target volume is contoured, along with all critical structures (OARs),
- Treatment planners will create a plan with multiple beams (or arc therapy) and beam weight to ensure maximum dose to planned tumor volume (PTV) and minimum dose to OARs,
- Dose-Volume Histogram (DVH) is generated for visual representation of the dose and volume that target volume & critical structures receive during the RT treatment,
- Rad Onc reviews plans and approves the appropriate one for the patient.

14

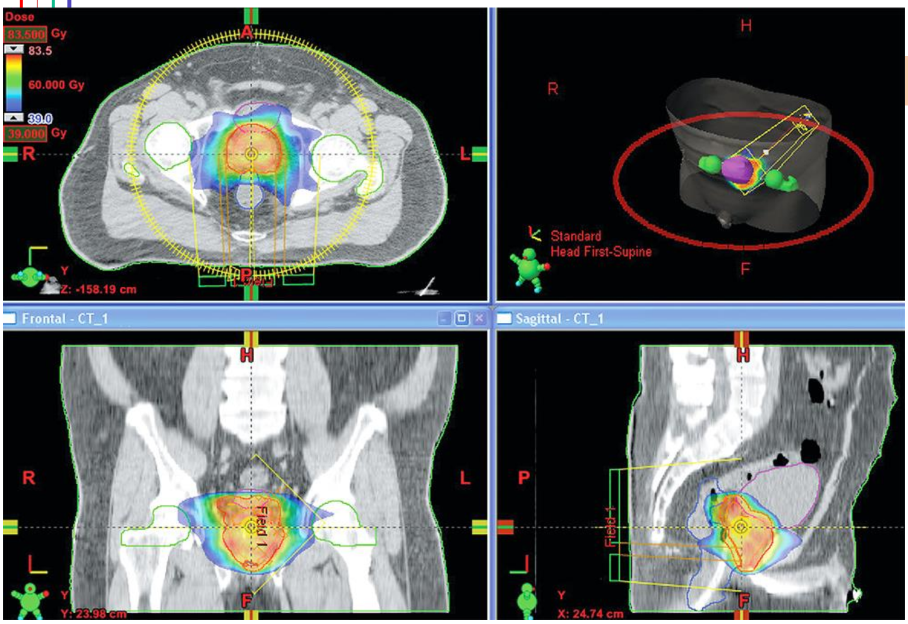
# PTV/OAR contouring-Lung




**PTV**: Planned Tumor Volume
**ITV**: Internal Tumor Volume (anticipates tumor motion)
**CTV**: Clinical Tumor Volume
**GTV**: Gross Tumor Volume

15

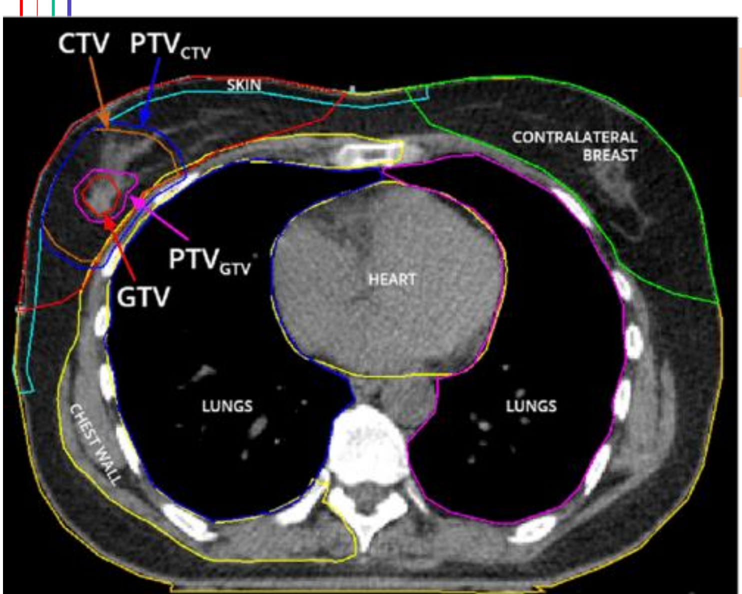
# PTV & OAR contouring-Prostate




Professional organizations publish contouring guidelines for radiation oncologists.

16

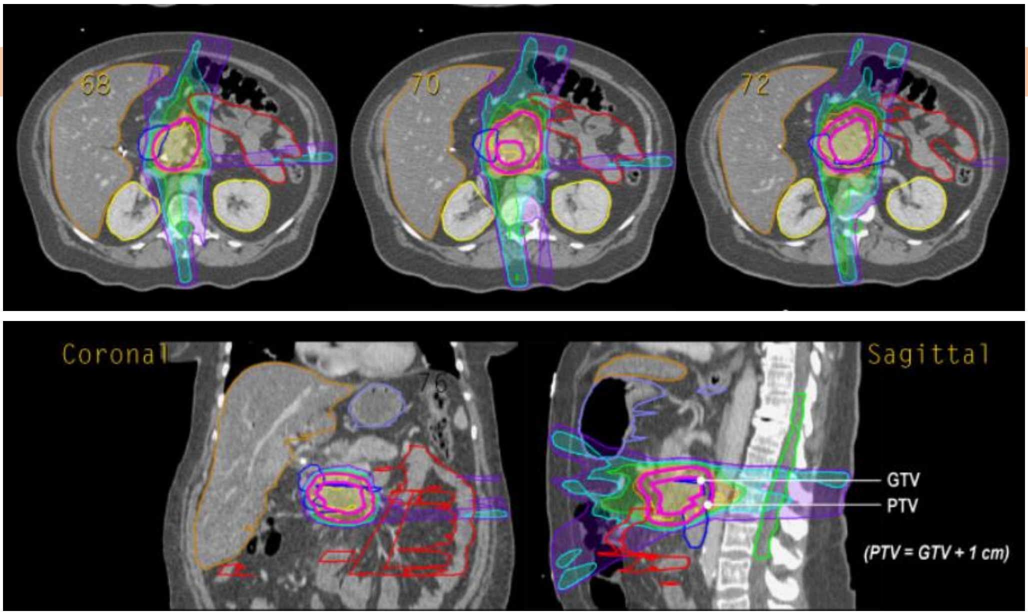
# PTV/OAR contouring-Breast




- Contralateral breast irradiation: risk of contralateral breast cancer is higher for women < 40 yrs of age,
  Risk factor for this age group who receive ≥ 1 Gy is estimated @ 17% f or contralateral breast cancer.
  Modern IGRT reduces dose to contralateral breast.
- Mean heart dose for LT-sided breast cancer is 3.6 Gy. Breath hold techniques can reduce it to 1.7 Gy.
- Including IMNs poses a greater risk to the heart.
- Prone breast boards can also reduce dose to heart.

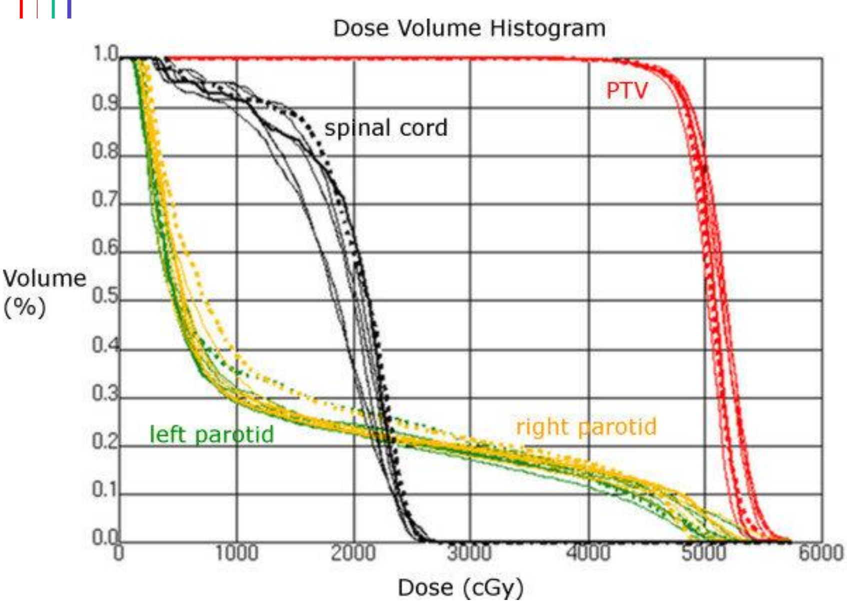
17

# PTV/OAR contouring-Pancreas



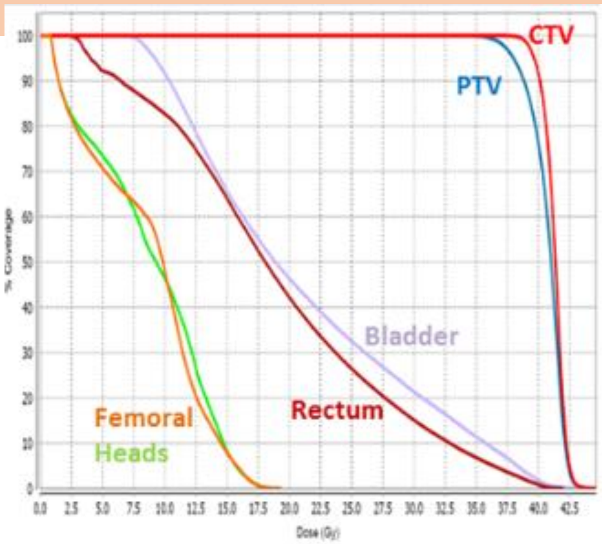

18

# Dose-Volume Histogram (DVH)-H&N



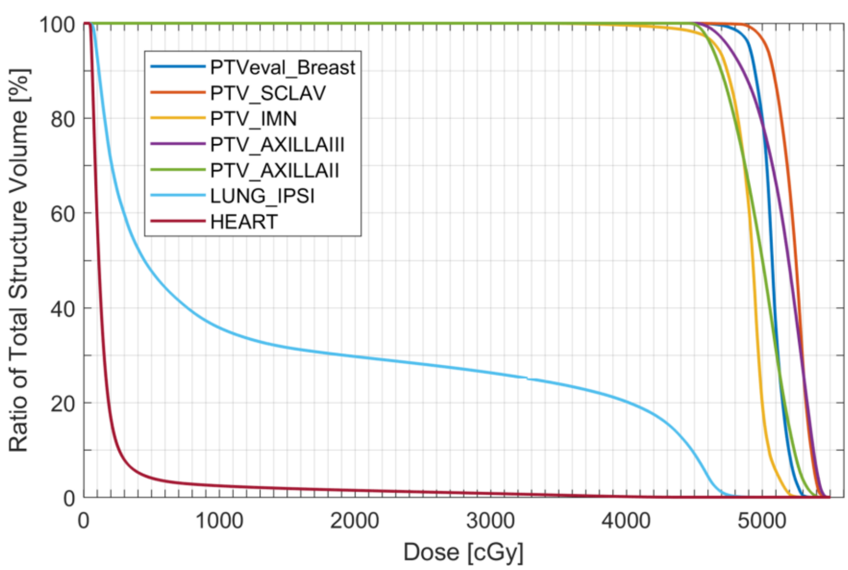

19

# Dose-Volume Histogram (DVH)-Prostate




20

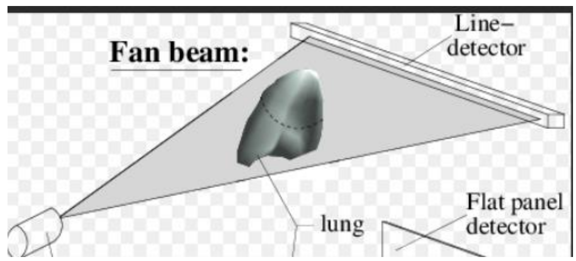
# Dose-Volume Histogram (DVH)- Breast




21

# Cone beam CT (CBCT)

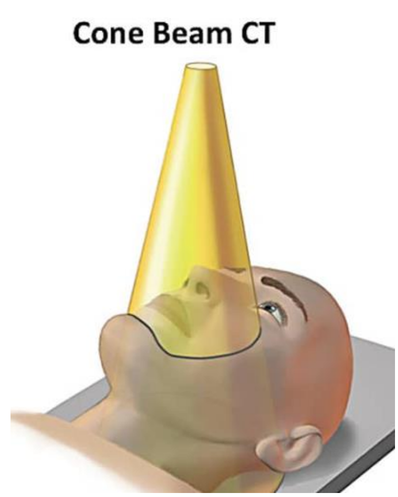
- Conventional CTs acquire images using a “Fan” photon beam geometry, as it rotates about the patient,
- Patient moves across the line detector to acquire the image,
- **Axial** non-volumetric scanning, suitable for stable organs (little or no motion),
- **Helical** scanning suitable for moving organs (heart, lungs)




22

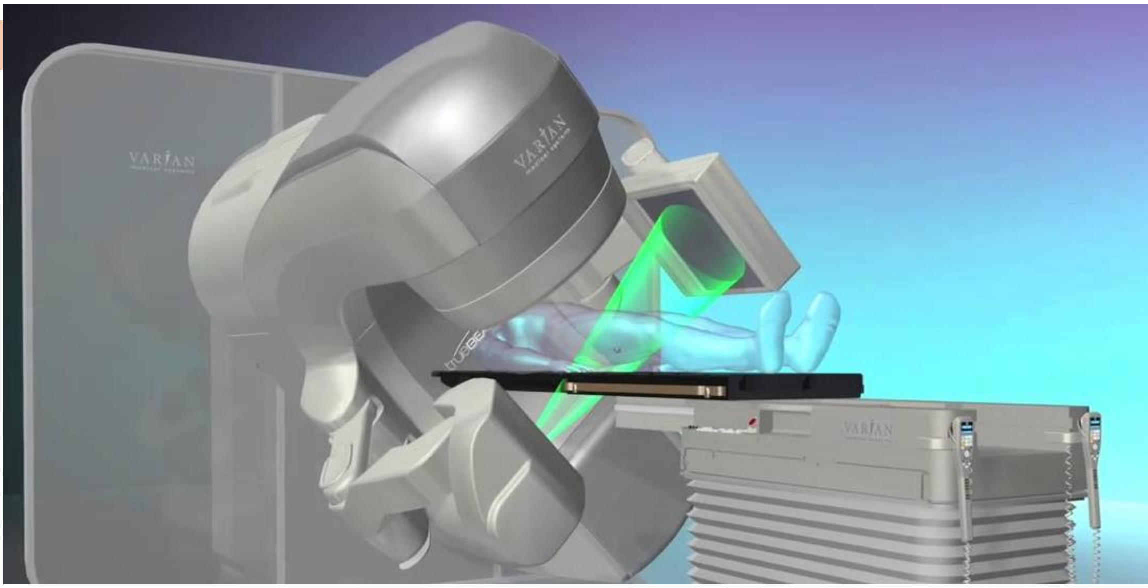
# Cone beam CT (CBCT)

- Cone beam CT comes from the cone shape the photon beam forms when acquiring an image; similar to radiation therapy dose delivery in photon modality.
- Can be acquired in the **Kv** (preferred) or **MV** range:
- MV CBCT
- Kv CBCT
- All part of Image Guided Radiation Therapy (IGRT).



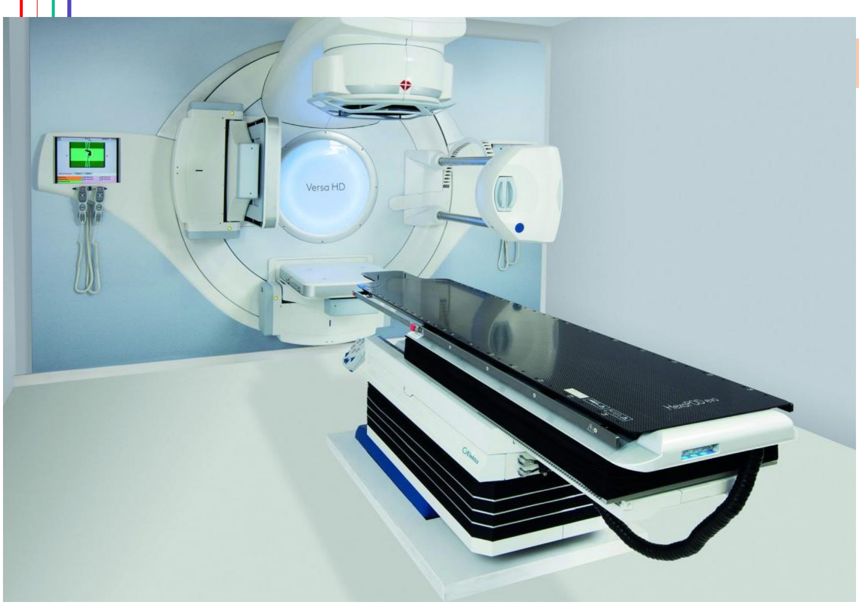

23

# Linac CBCT-Varian




24

# Linac CBCT-Elekta Versa HD




- All modern linear accelerators (Linacs) contain a sophisticated built-in imaging system (IGRT),
- IGRT allows for precise monitoring of any subtle and major changes to tumor volume and critical structures, to ensure accurate delivery of tumoricidal dose,
- Allows for re-evaluation of original treatment plan, making adaptive RT possible.
- Imaging(IGRT) **not associated** with any modality/treatment plan coding.

25

# Stereotactic Magnetic Resonance-Guided Adaptive Radiotherapy (SMART)

- MRI-based IGRT linear accelerators
- Elekta Unity: **7 MV**, FFF

MRIDIAN View Ray: **6 MV**, FFF



**Linacs that deliver RT in photon mode-02**

26

# Stereotactic Magnetic Resonance-Guided Adaptive Radiotherapy (SMART)

- MR images w/ high tissue contrast, superior to CT scans,
- Helps to improve quality of contouring of target organ & organs at risk,
- Valuable in its ability to identify intra-prostatic lesions for more precise boost plans,
- Possible to perform online adaptive RT; takes longer than CT-based,
- ~$8 million per unit w/ ~ half million/per yr maintenance.

**Coding Note**: MRI-based Linacs are linear accelerators that administer treatment with photon therapy in the MV range.

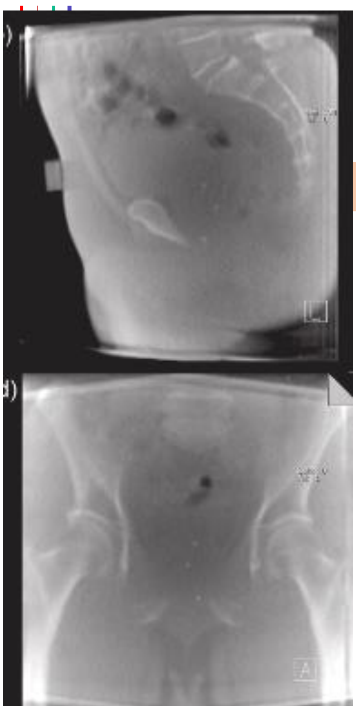
**Modality code**= 02, photons.

27

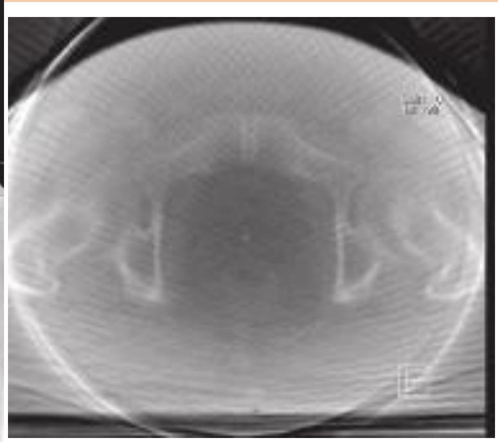
# MV CBCT

- Photons in megavoltage range,
- Due to photons interaction in MV range (Compton effect), images have low contrast; not Z dependent,
- Results in higher patient dose,
- Images tend to be grayish w/ no sharp definition; still useful in many RT scenarios.

28



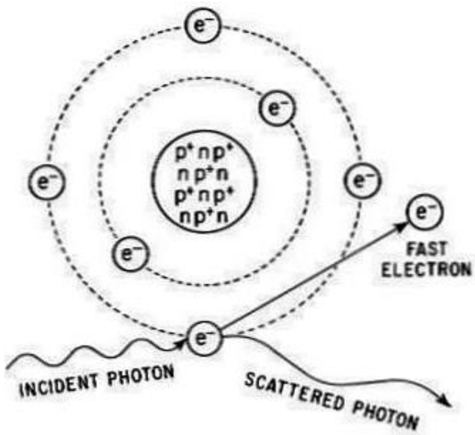
# MV CBCT



- Low contrast images,
- Results in more dose to patient

29

# Compton Interaction/Effect




- Valence shell electron is knocked off orbit.
- Incident photon is scattered and continues to interact, knocking off electrons from other atoms/molecules.
- Incident photon always retains some energy.
- Predominates in therapeutic range, MV.

Result: Ion pairs

Outer electron is knocked off its orbit

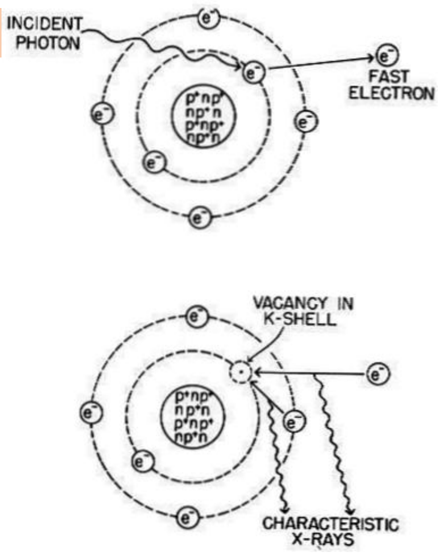
30

# **kV** CBCT

- Images are acquired with photons in the kV range,
- The **Photoelectric Effect(PE)** describes the photon interaction with tissue in the kV range,
- PE is proportional to $Z^3$
- Z-dependent: Imaged tissue with higher Z-equivalent values (bone) absorb more of the incident photons, creating light regions on the image; tissue with low Z- equivalent values (soft tissue, air cavities) absorb far less incident photons, allowing more photons to reach the detector, creating lighter regions on image,
- Greater contrast, more detailed images

31

# Photoelectric Effect (PE)




- Incident photon knocks out inner shell electron.
- All photon energy imparted on fast electron
- Electron from upper shell drops to fill vacancy, emitting characteristic x-rays
- Energy of characteristic x-rays is difference in binding energy of electrons
- **PE predominates in KV range**

$$PE = \frac{Z^3}{E^3}$$

32

## PE, Z equivalent & X-rays

$Soft\ Tissue\ Z_{eff}$= 7.1

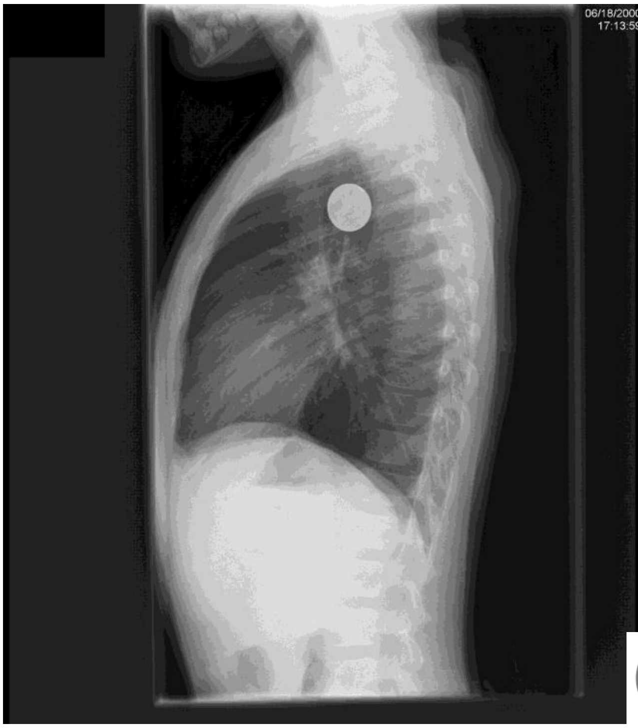
$Air\ Z_{eff}$= 7.7

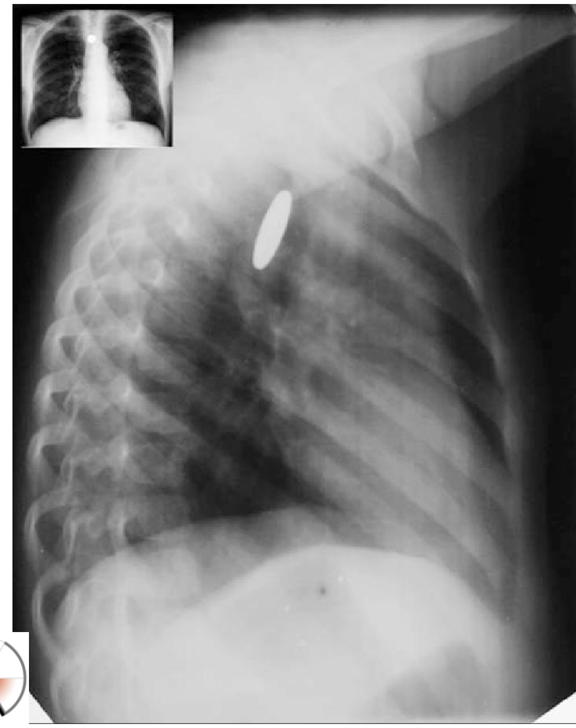
$Water\ Z_{eff}$= 7.5

$Bone\ Z_{eff}$= 11.6

*Barium Z*= 56

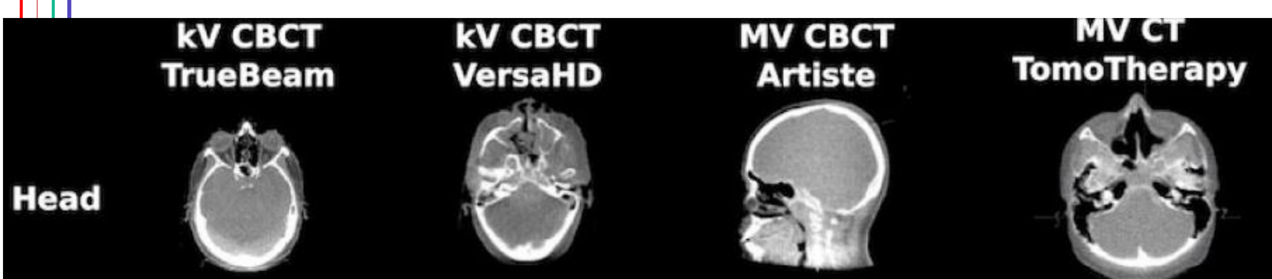
33



34

# kV CBCT




- High contrast images, greater detail.
- Approximate conventional diagnostic CTs in quality.

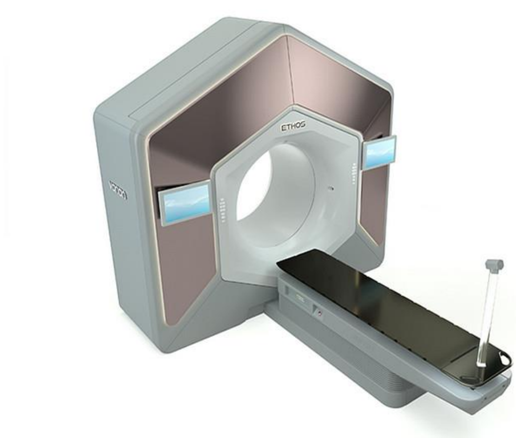
35

## kV/MV Cone Beam CT Summary

- Imaging process performed prior to delivery of RT treatments,
- Ensures accurate delivery of prescribed RT dose,
- Identifies any changes to patient positioning on treatment couch and allows for positioning correction,
- Monitors changes to the target volume, allowing for online adaptive RT.
- ***Does not refer to any treatment codes found in the STORE manual***.

36

## Varian Ethos: Adaptive RT




- CBCT imaging, fast image acquisition,
- Use of artificial intelligence to assist with contouring for treatment planning/delivery,
- Allows for online adaptive RT in short time frame (15-20 minutes), with AI assistance,
- **6 MV Flattening Filter Free (FFF) linac**, modified version of the Varian Halcyon.

37

# Varian Ethos-Potential Advantages

- Safer dose escalation,
- Margins reduction,
- Reduction in overall treatment time,
- Guarantee daily PTV coverage,
- Control daily OAR delivered dose,
- Reduce toxicity.

**New technology**, needs long-term follow to confirm projected advantages. Currently over 30 facilities with Varian Ethos worldwide, ~20 in the US.

38

# Varian Ethos-Setup, CBCT
## HyperSight

- Kv CBCT imaging capture in 17 seconds,
- Using AI, system will contour healthy tissues/organs within 15-30 seconds,
- After contoured plans are approved/accepted, system generates "adaptive" plan based on AI generated contours and MD's treatment objectives,
- New IMRT plan can be generated for pt while on the treatment couch within 2.5 minutes,
- QA is performed on the new parameters/plans; once approved, treatment is delivered in < 2 minutes for VMAT/IMRT plans.
- Designed to allow entire setup, CBCT, generation of new online adaptive plans and treatment delivery within the 15-minute treatment slots.

39

# Image Guided Radiation Therapy-IGRT: Many flavors…

- Cone-Beam Computed Tomography-Guided Stereotactic Adaptive Radiation Therapy (CT-STAR),
- Stereotactic MR-Guided Adaptive RT (SMART),
- Adaptive Radiation Therapy (ART),
- HyperSight (Varian CBCT),
- MRgRT/MRIgRT: MR-guided Radiation Therapy
- Image Guided Adaptive RT(IGART)
- Biology-Guided RT

**Common thread**: Imaging system based on Linacs, predominantly used for delivery of photon therapy-02.

40

# IGRT & Treatment Coding scenario 1

- Multiple cases where the RT treatment is described as SBRT or IMRT with Cone Beam Planning CT. *Should Cone Beam CT be equated with code 09-CT Online Adaptive Planning*?
- Pt taken to CT simulator. Axial images obtained through thorax. Images transferred to treatment planning system for 3D conformal RT planning. Diagnostic images merged with planning CT plan to assist with target volume contouring.
- Plan: RT to LT Lat $4^{th}$ rib, 3,000 cGy in 3 fx.
- RT completion summary:

| Site | Energy | Dose/fx | # fx | Start Date | End Date |
|---|---|---|---|---|---|
| LT Rib | 10x/FFF/SBRT | 1,000 | 3 | 5/12/23 | 5/17/23 |

41

# IGRT & Treatment Coding scenario 1…

- CBCT use for planning purposes during simulation procedure should not be equated to CT-guided online adaptive therapy,
- Image transfer to treatment planning system is an integral part of the simulation procedure and **does not** involve treatment,
- For code 09 to be used, the patient must undergo a replanning based on IGRT findings that merit the changes to the original simulation plan. This step takes place **after** the patient has started RT treatment.

42

# IGRT & Treatment Coding scenario 2

**Question**: How are we to interpret "Daily kV/kV IGRT" for coding purposes?

- Daily imaging during a pt's course of RT treatment is standard QA procedure to ensure accuracy of treatment delivery, monitor any significant changes to planned tumor volume (PTV) and organs at risk (OAR),
- IGRT simply means that we rely on daily imaging (MV CBCT or kV CBCT) to administer the prescribed dose; **Imaging ≠ Treatment** (no codes associated w/ imaging).

43

# IGRT & Treatment Coding scenario 3

**Question**: RT summary states VMAT with daily CBCT. 5 Gy x 7 fx, Left lower lobe, lung. How does CBCT impact modality or planning technique code? How should we code each?

- CBCT is part of IGRT, consisting of daily imaging (MV CBCT or kV CBCT) for QA purposes and evaluation of existing RT plan,
- VMAT is delivered using a Linac in **photon mode**, 02,
- Planning technique for VMAT can be 05-IMRT, or 06-SBRT.

44

# IGRT & Treatment Coding scenario 4

**Question**: How should the planning technique be coded for this case? The RT completion summary stated, "**Image Guidance: Cone beam CT**".

| Site | Energy | Dose/fx | # fx | Start date | End date |
|---|---|---|---|---|---|
| RUL, lung | 6 MV/SBRT | 1,000 | 5 | 3/28/23 | 4/9/23 |

**Modality code**= 02, photons (Linac with 6 MV beam energy used),

**Planning technique**= 06, SBRT (specifically mentioned in completion summary)

45

# IGRT Summary

Practical Radiation Oncology, 2023, 13, 97-111

- ✓Used @ ~ 98% of radiation oncology facilities nationwide,
- ✓CBCT use increased from 32.6% in 2010 to 95.8% in 2017,
- ✓Involves more complex imaging procedures requiring appropriate training and more extensive QA, personnel and equipment commissioning & maintenance,
- ✓Allows for reduction of PTV and more precise contouring of OARs; reducing toxicities,
- ✓Quality and safety component a must!
- ✓Increase in use of IGRT can result in additional dose to the patient during treatment.

46

# IGRT Summary

IGRT, however it is performed, is not associated with any radiation therapy codes in the STORE Manual!

47

48


EEBH
CTV
SMART
GTV
CT STAR
BID
Rarc
CSI
SART
Quad Shot
TPS
OAR
CBCT
Dmax
ETHOS
SCLV
IFRT
PTV
DVH
49

49

# Questions??

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# Fabulous Prizes

14

## Coming UP…

- Liver and Bile Ducts
  - Denise Harrison, BS, CTR
- Pancreas
  - Vicki Hawhee, Med, CTR

## CE Certificate Quiz/Survey

CE Phrase

Link

Thank you!!!