Welcome to ROB:
An Introduction to Radiation Oncology

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Radiation Oncology Branch

National Cancer Institute | National Institutes of Health

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Introduction to Radiation Oncology

- Asks:
  - What is ROB?
  - What do we do?
  - What to do if you have a protocol that includes RT?
  - What are the general types of RT?
    - What is available at NIH?
  - What are common acute and late toxicities of RT?

Introduction to Radiation Oncology

- Learning objectives:
  - To provide an overview of ROB
  - To recognize the role for RT in oncologic care
  - To define radiation oncology as a practice
  - To describe various treatment options
  - To define some commonly used terminology
  - To briefly review indications for urgent RT

Overview of ROB

- Radiation Oncology Branch
- Part of the NCI / CCR
- Located on B2-3500
- Clinic # 301-496-5457

- Service Mission
  - Clinical care service that provides RT for patients at the CC
- Research Mission
  - Conduct pre-clinical and clinical research on the biologic and therapeutic effects of RT

Overview of ROB

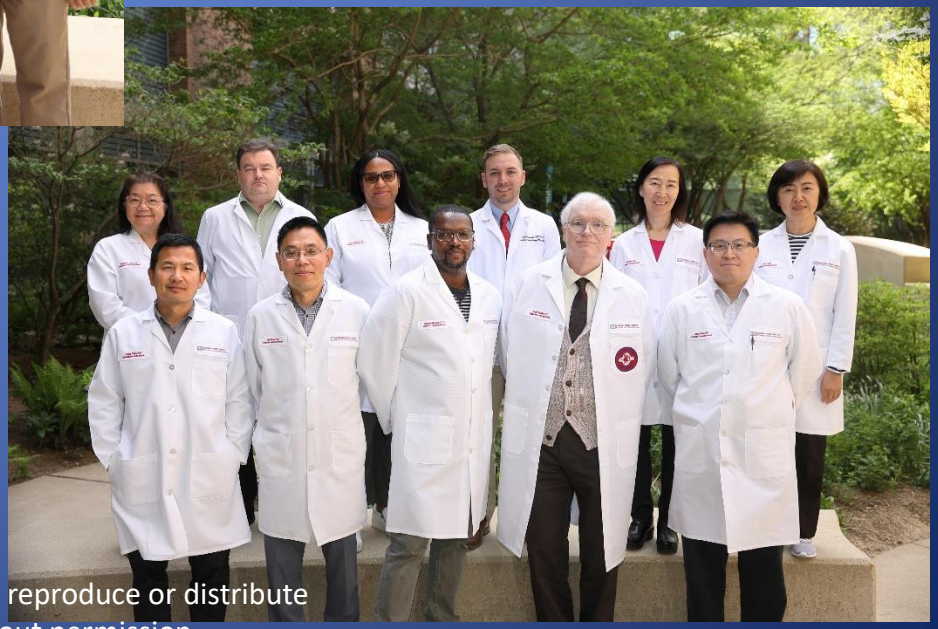
Who are we?

- A team of providers specialized in radiotherapy
  - Patient support and administrative staff
  - Research and clinical center nursing
  - Radiation therapists
  - Physicists and dosimetrists
  - Nurse practitioners and physicians

Radiation Oncologists

- Kevin Camphausen
  - ROB Chief, CNS
- Jeffrey Buchsbaum
  - Peds, TBI, H+N, Palliative
- Huma Chaudhry
  - CNS
- Deborah Citrin
  - GU
- Freddy Escorcia
  - GI, Radiopharmaceutical Therapy
- Jennifer Jones
  - Thoracic, Lymphoma, Immunotherapy
- Andra Krauze
  - CNS, GU, H+N
- Peter Mathen
  - CNS, Palliative
- Krishnan Patel
  - Prostate
- Kilian Salerno
  - Sarcoma, Rare Tumors, GI, Breast, TBI, Palliative
- DeeDee Smart
  - CNS, Meningioma, Brain Mets, Radiation-Induced Neurologic Injury

ROB Clinical Staff



ROB Clinical Staff

Nurse Practitioners

- Yoldy Dorisca
- Nancy Garren
- Megan Mackey
- Erica Schott

Research Nurses

- Tess Cooley Zgela
- Debbie Nathan

Research Support

- Betsaida Benitez
- Matthew Masciocchi

CC Nurses

- Beth Heneghan
- Jess Telismond
- Amy Wilkins

Physicists/Dosimetrists

- Barbara Arora
- Jason Cheng
- Peter Guion
- Bo Li
- Robert Miller
- Holly Ning

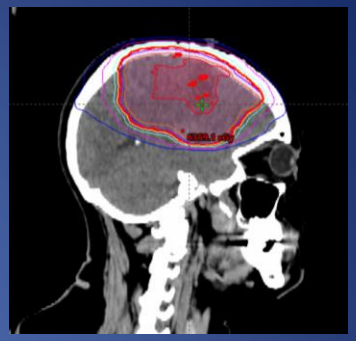
Radiation Therapists

- Latoya Hinton
- Dramane Niambele
- Brock Stocksdale
- Eleanor Williamson-Taylor

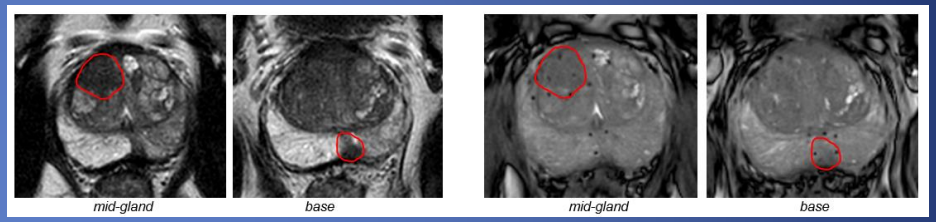
Patient Support

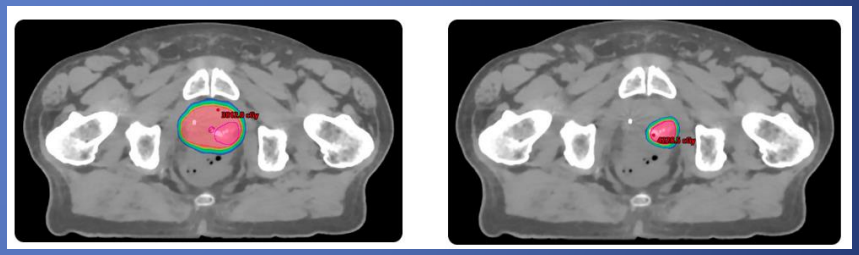
- Stephanie White
- Stephanie Van Werry

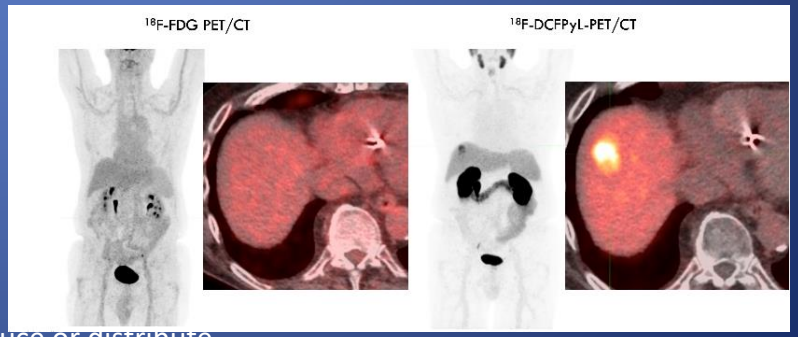
ROB Protocols



- Hypofractionation
- Radiosensitizer + RT
- Re-irradiation
- Focal treatments
- Imaging and response assessment
- Late effects and natural history
- Management of toxicity







Interventional Protocols/Clinical Trials

Prostate:

- IRB001713 Surface electrical stimulation for urinary incontinence
- 000611 FOCUS-RT Focal therapy with SBRT
- 000481 DCFPyl to assess response to SBRT
- 000328 Biolen: Bicalutamide implants with RT
- 18C-0028 Ph1 Hypofx dose escalated post-prostatectomy RT
- 17C-0153 Ph1 dose escalated SBRT for recurrence after prior RT
- 13C-0119 Imaging studies to assess response to RT

Interventional Protocols/Clinical Trials

CNS:

- IRB001859 Ph1 Hypofx re-irradiation for recurrent GBM
- 20C-0027 Ph1 Selinexor + temozolomide and RT for GBM
- 16C-0081 Ph1 Dose escalation for re-irradiation for recurrent GBM

GI (MIB):

- 000080 DCFPyl in hepatocellular carcinoma

Selected Other Protocols

- 09C-0100 HDR brachytherapy
- 08C-0214 Neuropsych outcomes following whole brain RT for brain mets
- 00C-0074 Late effects and natural history post RT
- 02C-0064 and 04C-0200 Blood-urine collection
- 79C-0111 Mastectomy vs RT in breast cancer

Overview of ROB

- Provide support for intramural protocols
  - Those that include RT as a part of protocol therapy
    - Ex. SABR/SBRT
      TBI - 15 different protocols
  - Those that allow RT while on protocol
    - Palliative RT*
- Clinical consultative service
    - Emergent or urgent indications
    - General oncologic care

Overview of ROB

- What to do if you have a protocol/concept that includes RT?
  - Reach out early
  - Link with a ROB physician as an AI
  - Will review the protocol regarding use of RT
    - Scientific rationale, feasibility, and safety
  - Will present within ROB and provide feedback
  - Required for ROB support

Overview of ROB

- How to reach us:
  - Doc of the day covering each clinic day
  - Radiation oncologist on call
  - Call the ROB clinic
  - Call or email me
  - Can reach out to Tess or Debbie

Introduction to Radiation Oncology

- Learning objectives:
  - To provide an overview of ROB
  - To define radiation oncology as a practice
  - To recognize the role for RT in oncologic care
  - To describe various treatment options
  - To define commonly used terminology
  - To briefly review indications for urgent RT

Introduction to Radiation Oncology

- What is radiation oncology?
  - The use of various forms of radiation in the treatment of disease
  - Goal to deliver treatment dose to target while minimizing dose to adjacent normal tissues

Introduction to Radiation Oncology

- ACS Cancer Statistics:
  - >2 million new cancer cases and 611,720 cancer deaths projected in 2024
  - Second most common cause of death in the US
  - 60% of all cancer patients will receive RT during their care
  - RT intent is curative for 50-75% of patients

Siegel et al, CA Cancer J Clin 2024

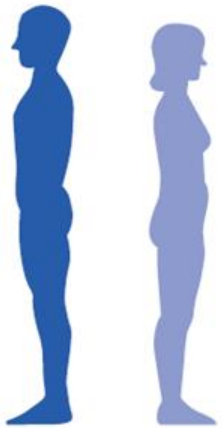
Cancer Statistics 2024

Estimated number of new cancer cases in the US in 2024

American Cancer Society

Estimated New Cases

Male			Female		
Prostate	299,010	29%	Breast	310,720	32%
Lung & bronchus	116,310	11%	Lung & bronchus	118,270	12%
Colon & rectum	81,540	8%	Colon & rectum	71,270	7%
Urinary bladder	63,070	6%	Uterine corpus	67,880	7%
Melanoma of the skin	59,170	6%	Melanoma of the skin	41,470	4%
Kidney & renal pelvis	52,380	5%	Non-Hodgkin lymphoma	36,030	4%
Non-Hodgkin lymphoma	44,590	4%	Pancreas	31,910	3%
Oral cavity & pharynx	41,510	4%	Thyroid	31,520	3%
Leukemia	36,450	4%	Kidney & renal pelvis	29,230	3%
Pancreas	34,530	3%	Leukemia	26,320	3%
All sites	**1,029,080**		**All sites**	**972,060**	



Excludes basal cell and squamous cell skin cancers and in situ carcinoma except urinary bladder.
Source: American Cancer Society, 2024.

Siegel et al, CA Cancer J Clin 2024

Radiation Oncology

- Radiation therapy is an integral part of oncologic care for many patients
- Many treatment options, indications, and modalities

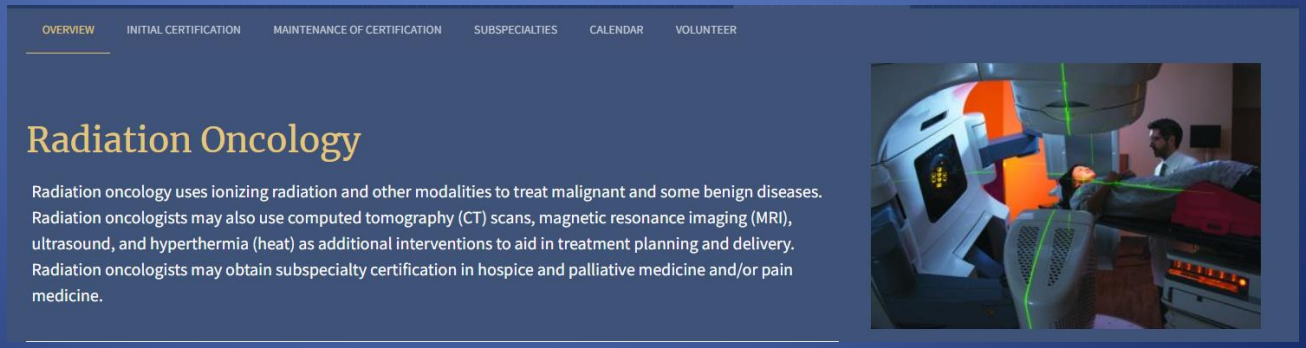
Radiation Oncology Training

- Separate medical specialty
- 5 years of residency training
  - 1 year transitional/preliminary year
  - 4 years of residency
- Boarded by ABR
  - Distinct from diagnostic radiology

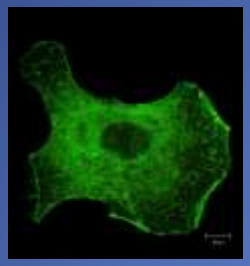
Radiation Oncology Board Certification

- Initial Certification
  - Qualifying exams
    - Radiation and Cancer Biology
    - Medical Physics
    - Clinical Radiation Oncology
  - Oral Boards
- MOC

ABR | American Board of Radiology



The Discipline of Radiation Oncology

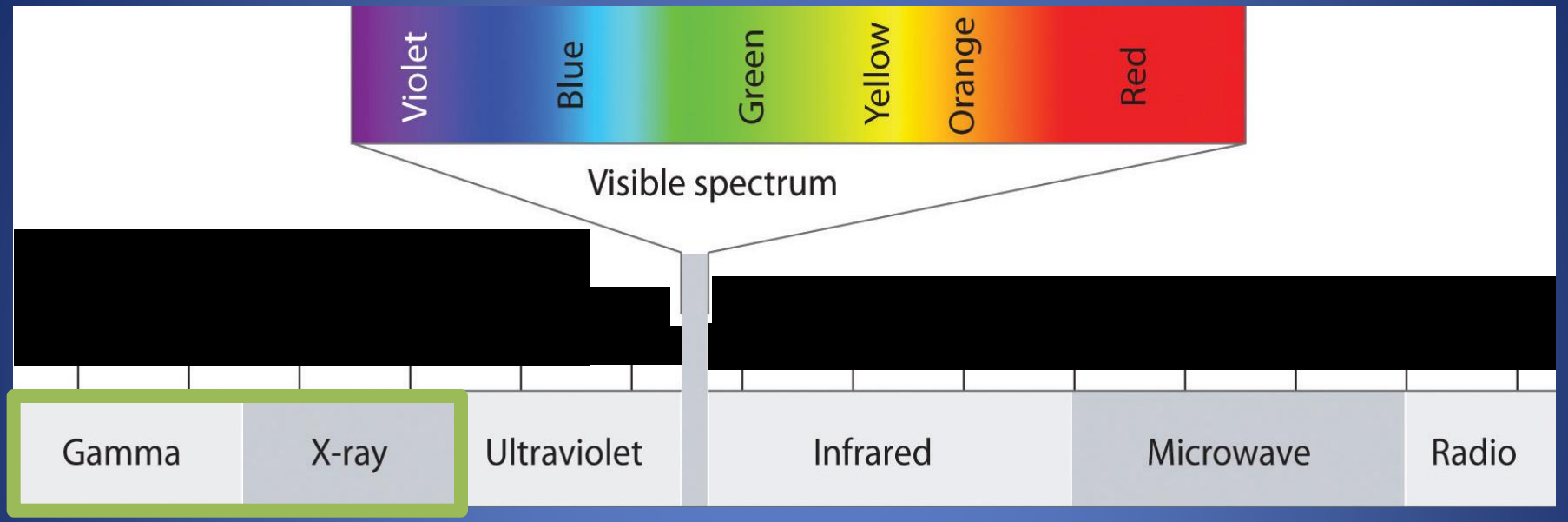


Radiation Biology

Physics

Radiation Therapy

Radiation Oncology: Physics

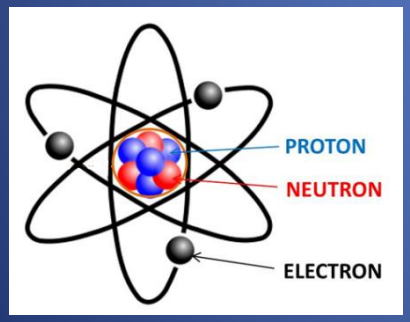


Radiation Oncology: Physics

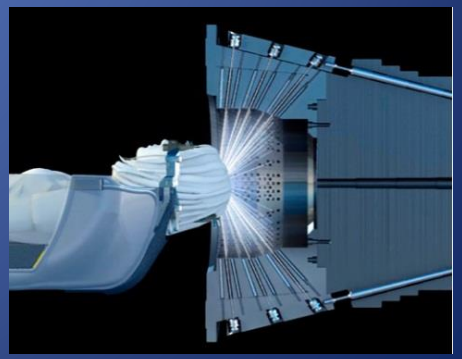
- X-rays
- Gamma rays

~90%

- Particles

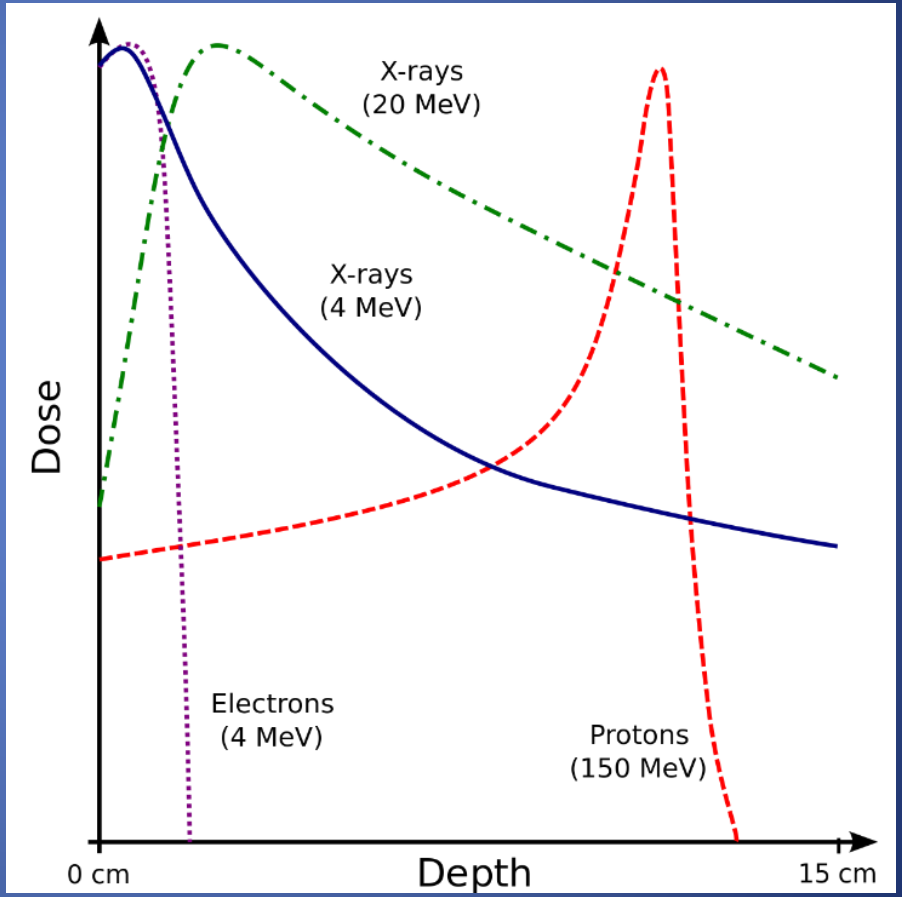


- Radioactive Sources



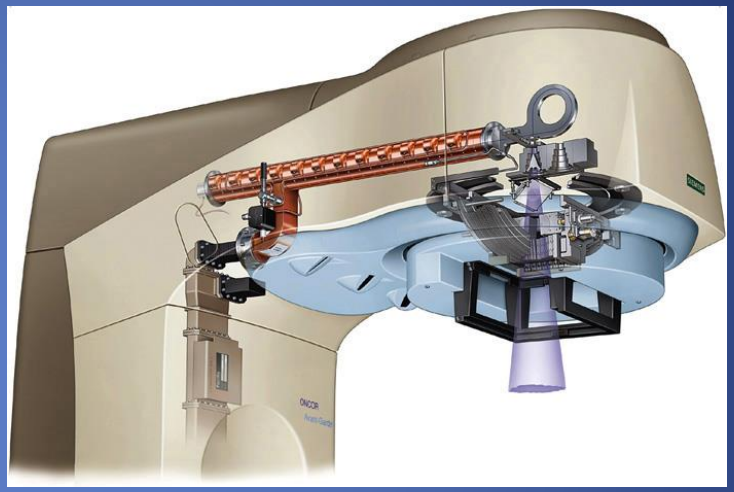
Physics: Ionizing Radiation

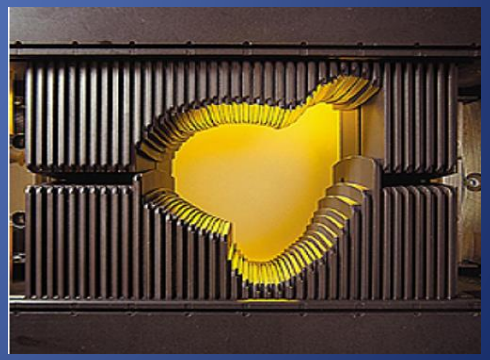
- Photons
  - Most common
- Electrons
  - Superficial targets
- Heavy particles
  - Protons
  - Neutrons
  - Carbon ions
    - Bragg peak**

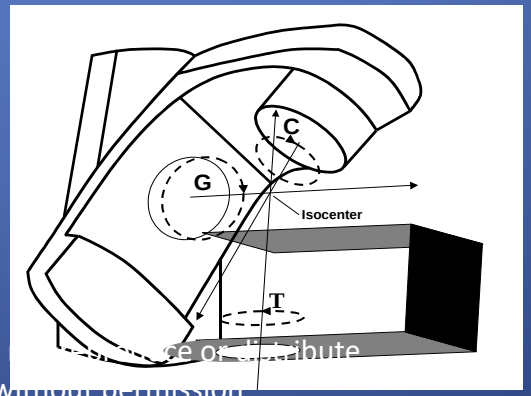


LINAC: Linear Accelerator

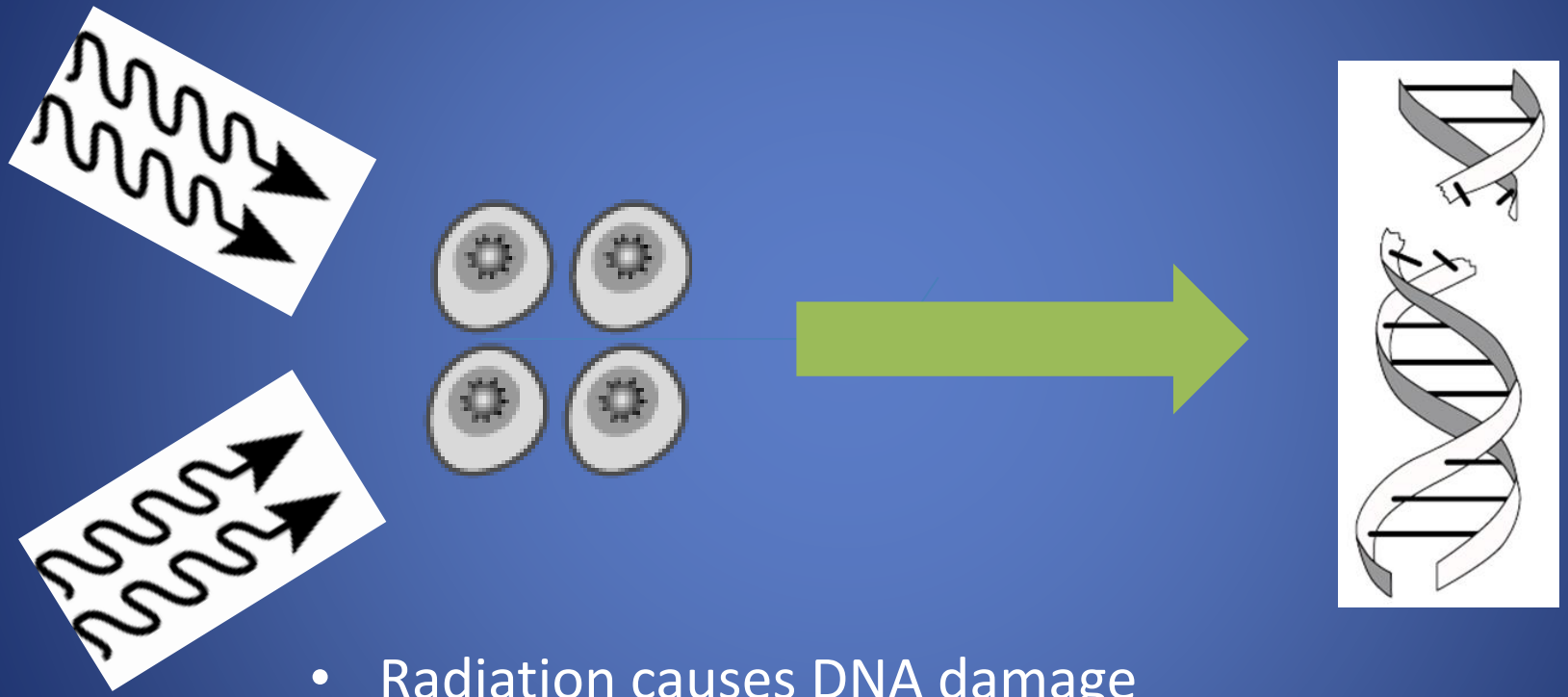
- High energy photons and electrons
- Uniform beam characteristics
- Field shaping: MLCs
- Treatment delivery
  - Gantry rotates
  - Couch rotates
- On board imaging







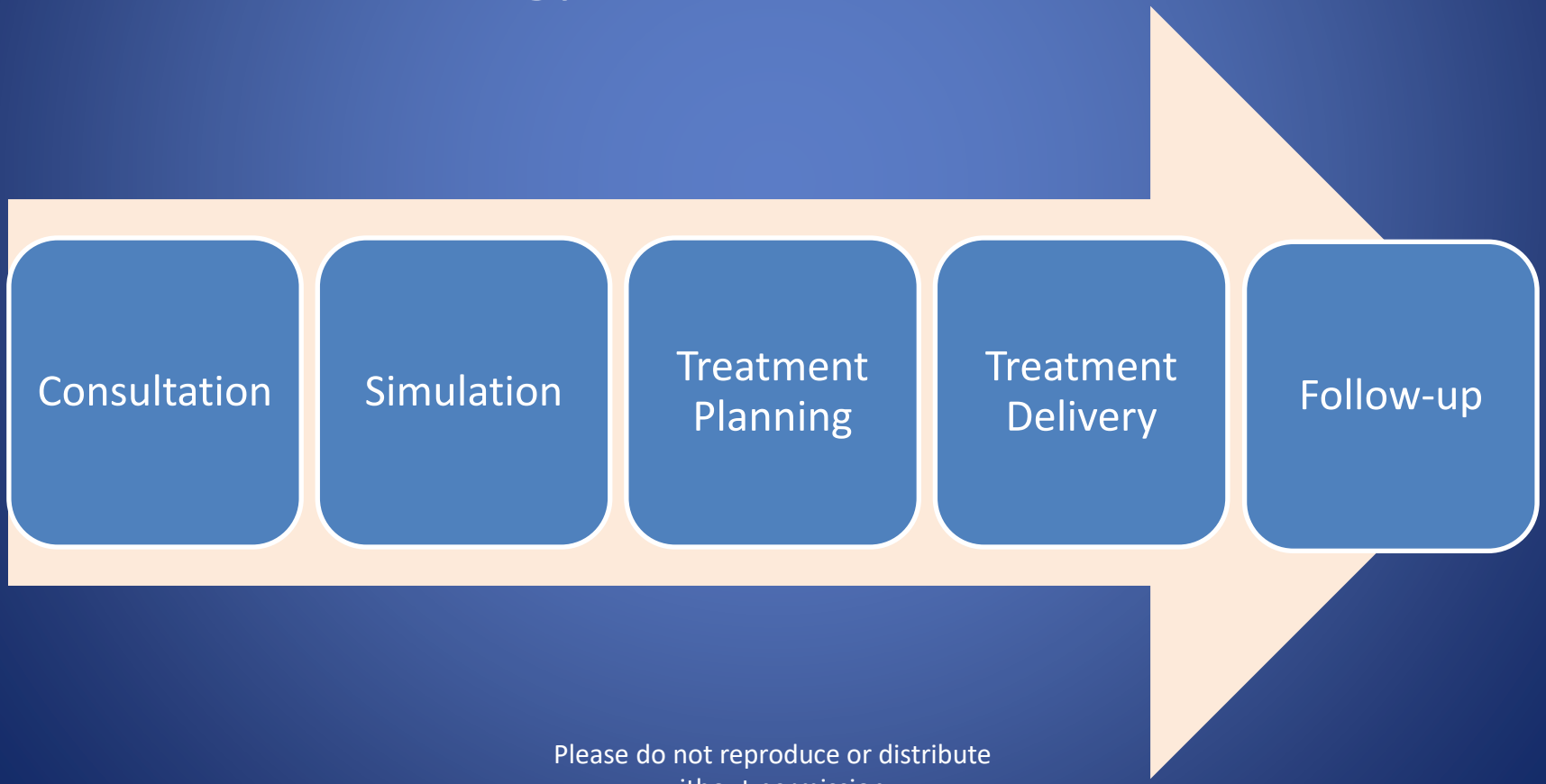
Radiation Oncology: Radiobiology



- Radiation causes DNA damage
  - **DNA DSBs** most lethal
- Radiation induced damage can cause cell death, carcinogenesis, and heritable mutations

Radiation Oncology: Logistics

- What happens when a patient is referred for a radiation oncology consultation?



Radiation Oncology Consultation

- Comprehensive evaluation that considers:
  - Patient factors
  - Treatment factors
  - Disease burden
  - Disease biology
  - Risks for disease morbidity vs treatment morbidity
  - Alternative treatment options

Radiation Oncology Consultation

- Determine if RT is indicated
- Define the treatment intent
- Determine the appropriate dose and modality
- Delineate the targets and normal tissues at risk
- Develop a treatment plan

Radiation Oncology Terminology: Treatment Options

- TREATMENT INTENT:
  - Definitive
  - (Neo)Adjuvant
  - Palliative
  - Prophylactic
- TARGETS:
  - Gross disease
  - Microscopic disease

Radiation Oncology Terminology: Dose

- ABSORBED DOSE:
  - Energy imparted per unit mass by ionizing radiation to matter at a specific point
  - J/kg

- Unit is **Gy** (Gray) or **cGy** (centiGray)

  - Formerly rad
  - 1 Gy = 100 rad

Radiation Oncology Terminology: Dose

What does “30 Gy” mean?	What does “5 fractions” mean?
30 Gy in 10 fractions	50 Gy in 5 fractions
30 Gy in 5 fractions	36.25 Gy in 5 fractions
30 Gy in 3 fractions	26 Gy in 5 fractions
30 Gy in 1 fraction	20 Gy in 5 fractions

The biologic effect of each of these regimens is very different

Radiation Oncology Terminology: Dose Fractionation

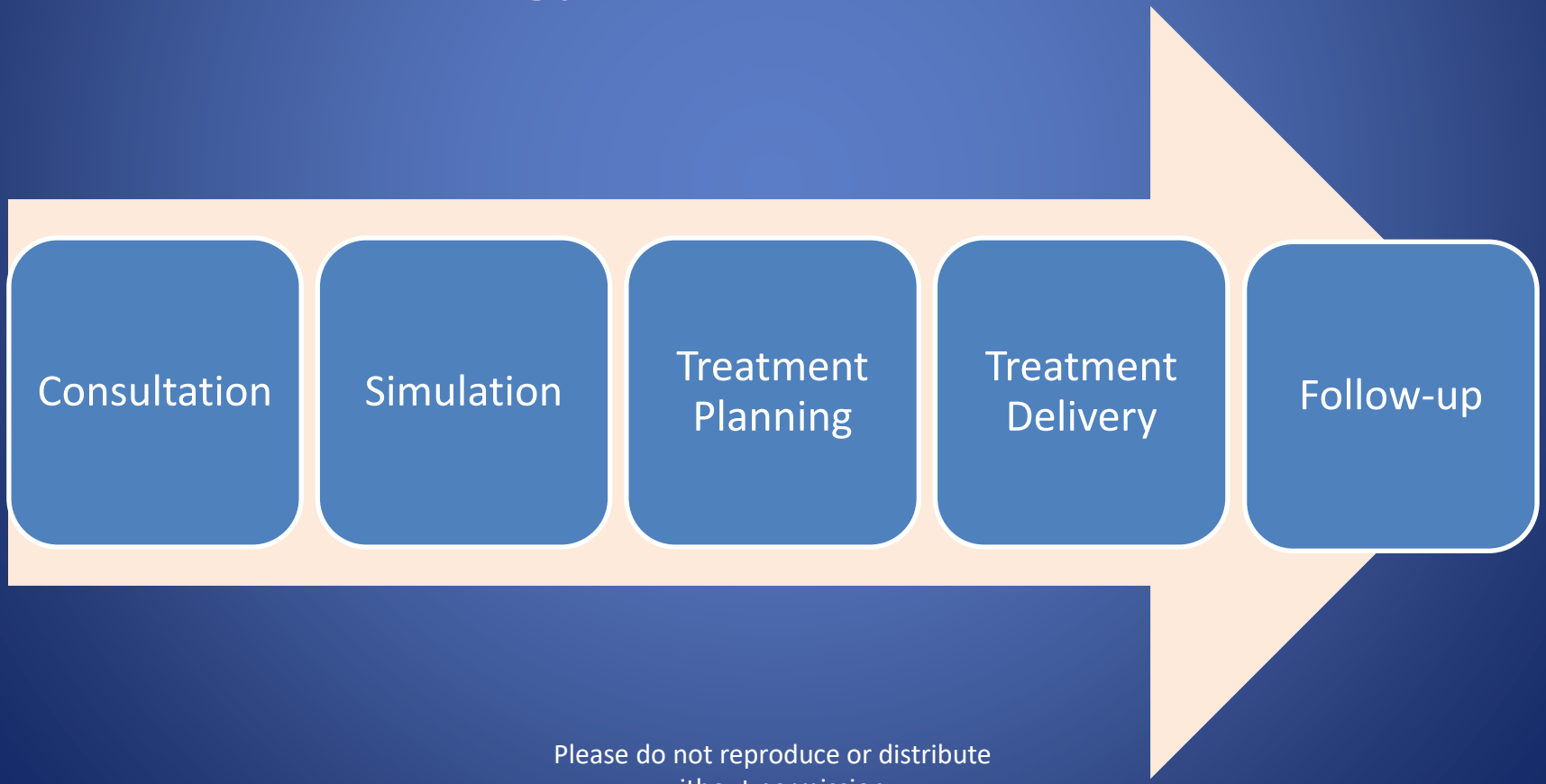
- **Conventional fractionation**
  - 1.8 – 2 Gy / fraction
  - Often 5 or more weeks
- **Hyperfractionation**
  - Smaller dose / fraction
    < 1.8 – 2 Gy / fraction
  - More fractions
  - Higher total dose
- Acceleration
  - Shortened treatment course
- **Hypofractionation**
  - Larger dose / fraction
    > 2 Gy / fraction
  - Fewer fractions
  - Shorter treatment course
  - Lower total dose
  - Moderate hypofractionation
    Often 3 weeks
  - Ultra-hypofractionation
    ≥ 5 Gy / fraction
    Very few fractions (≤ 5)

Radiation Oncology Terminology: Modalities

- **External Beam Radiation Therapy (EBRT)**
  - Superficial x-rays or “orthovoltage”
  - Photons
  - Electrons
  - Protons (PBT) and other heavy particles
- Brachytherapy
  - Radioactive sources
  - Cylinder, T+O, balloon, seeds, catheters, plaques, etc
- Radiopharmaceutical therapy (RPT)
- Intraoperative Radiation Therapy (IORT)

Radiation Oncology: Logistics

- What happens when a patient is referred for a radiation oncology consultation?



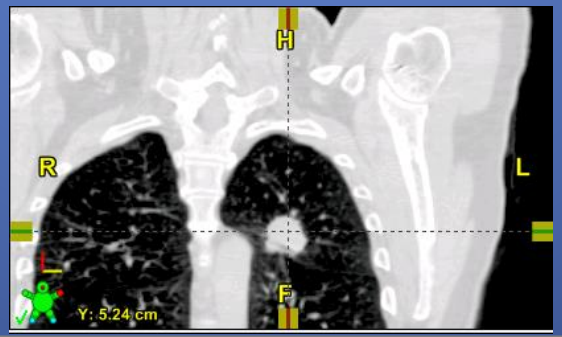
Simulation

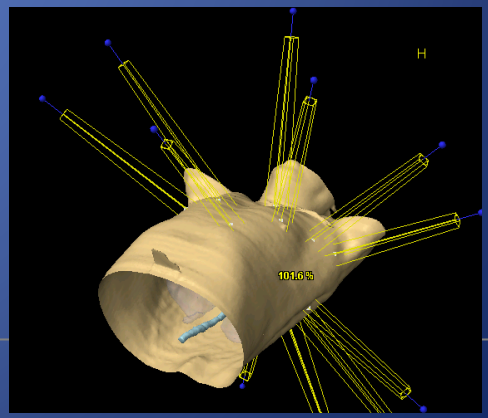
- Treatment planning session
  - Acquire set up parameters and axial images for treatment planning
  - CT, PET/CT, MR/CT

- Set up positioning
  - Reproducible
  - Immobilization devices
  - Isocenter placement
  - Tattoo markings

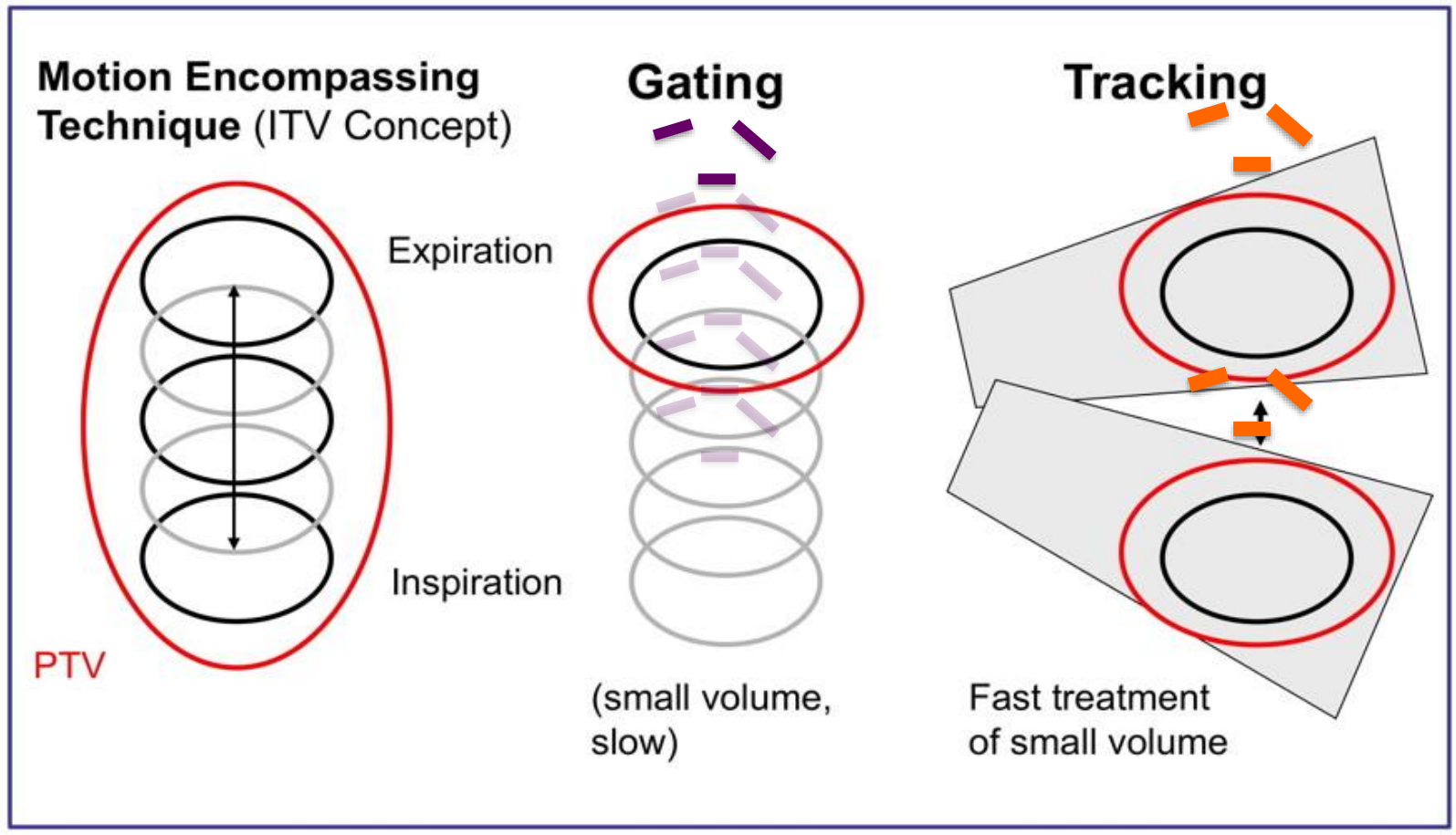
Simulation

- Contrast may be used
- Motion management as appropriate





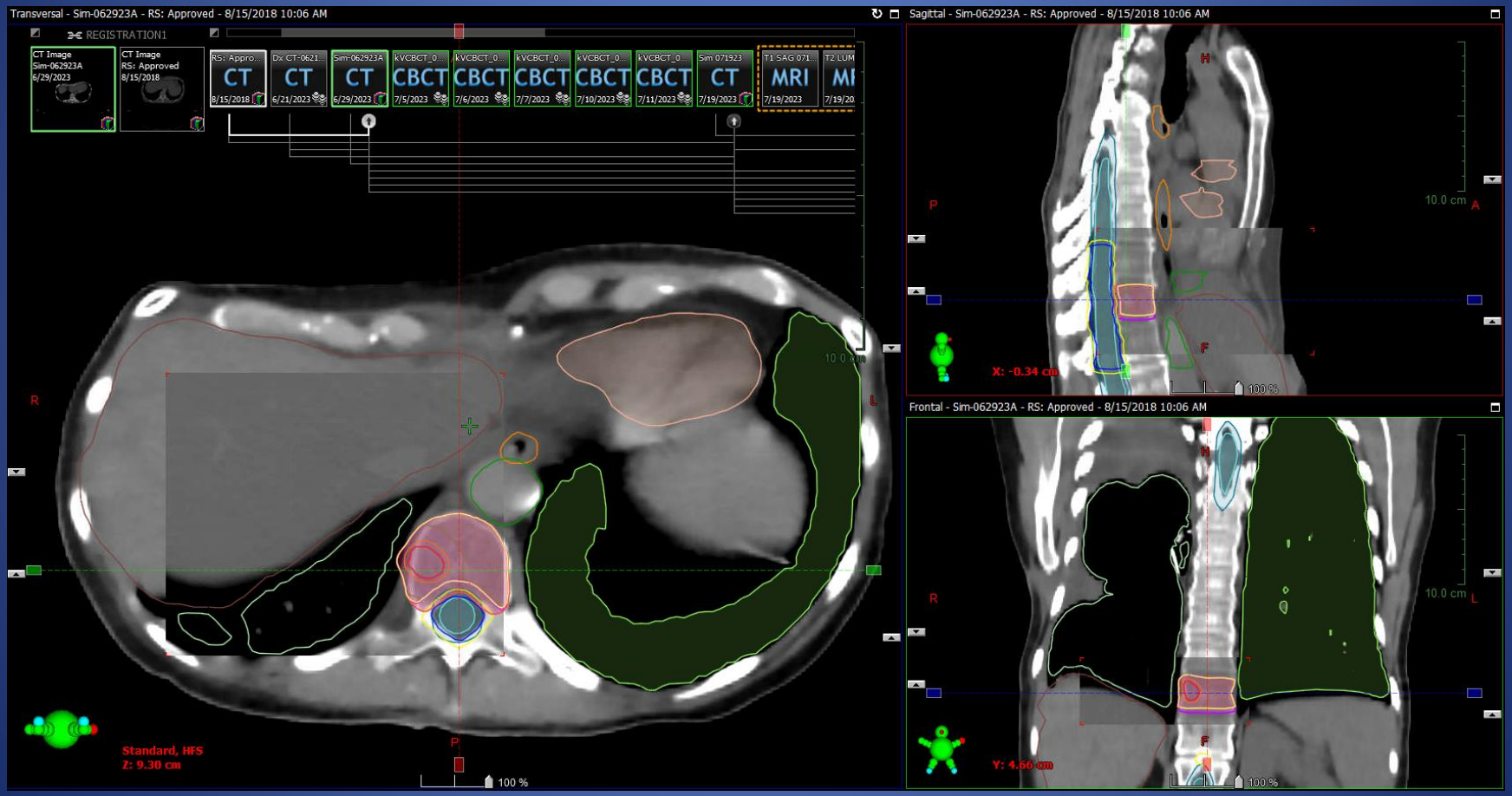
Motion Management



Radiation Treatment Planning

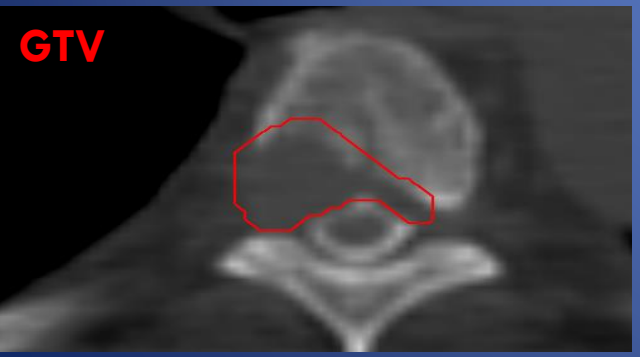
- Contouring
  - Delineation of appropriate targets and normal tissues/organs at risk (OARs)
- Dosimetry and Treatment Planning
  - Creation of plan ensuring target coverage and minimizing dose to normal tissues
- All plans have QA and peer review

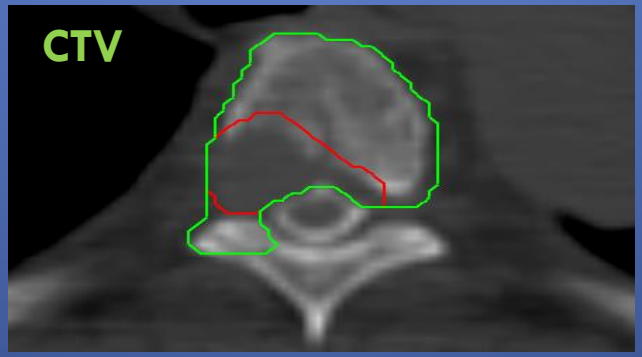
Image Fusion and Contouring



Target Delineation for Treatment Planning

- **GTV: Volume encompassing grossly visible tumor**
- **CTV: Volume to account for suspected microscopic spread**
- **PTV: Volume to account for geometric and other uncertainties**





Radiation Treatment Planning

How much dose can be delivered to specific organs?

- Dose constraints
- Vary by dose fractionation
- Vary by type of tissue
- Used to minimize risk of toxicity

Serial tissue	Contouring instructions	Volume	Volume max (Gy)	Max point dose (Gy)	Endpoint (grade ≥3)
Trachea and large bronchus	Contour the trachea and cartilage rings starting 10 cm superior to the PTV and extending inferior to the bronchi ending at the first bifurcation of the named lobar bronchus	<5 cm^3	52	59	Impairment of pulmonary toilet
Skin	The outer 0.5 cm of the body surface anywhere within the whole-body contour.	<10 cm^3	46.3	48.9	Ulceration
Stomach	The entire stomach wall and the gastric contents included from the GE junction to the proximal duodenum at the pyloris	<50 cm^3	33.9	45	Ulceration/fistula
Duodenum	The entire duodenal wall and lumen from the pyloris to the duodenojejunal flexure	<5 cm^3	33.9	45	Ulceration
Jejunum/ileum	Any and all loops of small bowel as 1 structure within 10 cm of the PTV in any direction.	<120 cm^3	33.9	41	Enteritis/ obstruction
Renal hilum/vascular trunk	Each side separately, including major calyces, renal pelvis, and proximal renal artery medial to the aorta	15 cm^3	30.7		Malignant hypertension
Colon	One structure, including wall and contents of lumen starting 10 cm superior to PTV and ending 10 cm below PTV	<20 cm^3	47	60	Colitis/fistula
Rectum (including stool)	One structure, including wall of rectum and all contents in lumen; start contouring 10 cm superior to PTV and then inferior to anal sphincter	<10 cm^3 <20 cm^3 <30 cm^3 <40 cm^3	52 49 46 43	65	Proctitis/fistula
Bladder (with urine)	Contour the bladder wall and all urine ending inferiorly at the base of the prostate	<90 cm^3 <125 cm^3	48 45	53	Cystitis/fistula
Bladder (suprapubic wall)	Contour the anterior inferior wall resting above and around the superior aspect of the pubic bone starting at the prostate inferiorly and extending 2-3 cm superiorly from there	<5 cm^3	23	42	Dysuria
Penile bulb	Contour starting superiorly at the inferior aspect of the pelvic diaphragm (urethral sphincter) and extending inferiorly and anteriorly up to 3 cm	<3 cm^3	38	44	Erectile dysfunction
Femoral heads	Contour both right and left separately	<10 cm^3	38	43.5	Necrosis
Parallel tissue		**Critical volume (cm^3)**	**Critical volume dose max (Gy)**	**Other constraints**	**Endpoint (grade ≥3)**
Lung (right and left) minus GTV	Contour right and left lung as 1, structure including all parenchymal lung tissue but excluding the GTV and major airways (trachea and main/lobar bronchi)	1500 for males and 950 for females*	15		Basic lung function
Lung (right and left) minus GTV	Contour right and left lung as 1 structure, including all parenchymal lung tissue but excluding the GTV and major airways (trachea and main/lobar bronchi)			V-16 Gy <37%	Pneumonitis
Liver minus GTV	Contour right and left lobes as 1 structure, including all parenchymal liver tissue but excluding the GTV and major draining ducts, extrahepatic portal vein, and gall bladder	700 cm^3*	27		Basic liver function
Renal cortex (right and left)	Contour right and left kidney as 1 structure, including all parenchymal capsular tissue but excluding the renal hilum/vascular trunk (see above)	200 cm^3*	21		Basic renal function

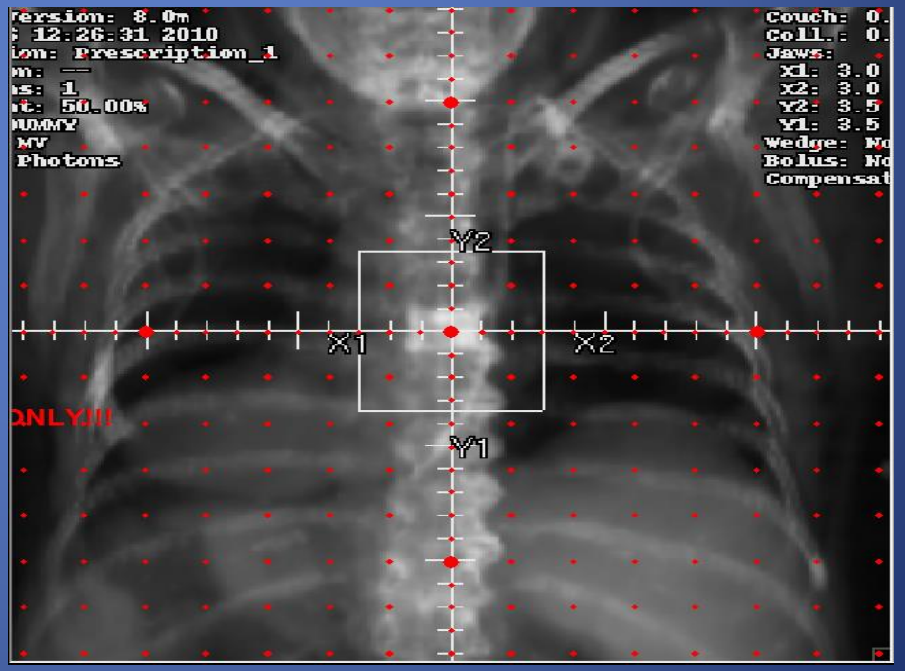
* One-third of the "native" total organ volume (before any resection or volume reducing disease), whichever is greater.
Abbreviations: CT = computed tomography; GE = gastroesophageal; GTV = gross target volume; PTV = planning target volume; TM = temporomandibular.

Timmerman, IJROBP 2021

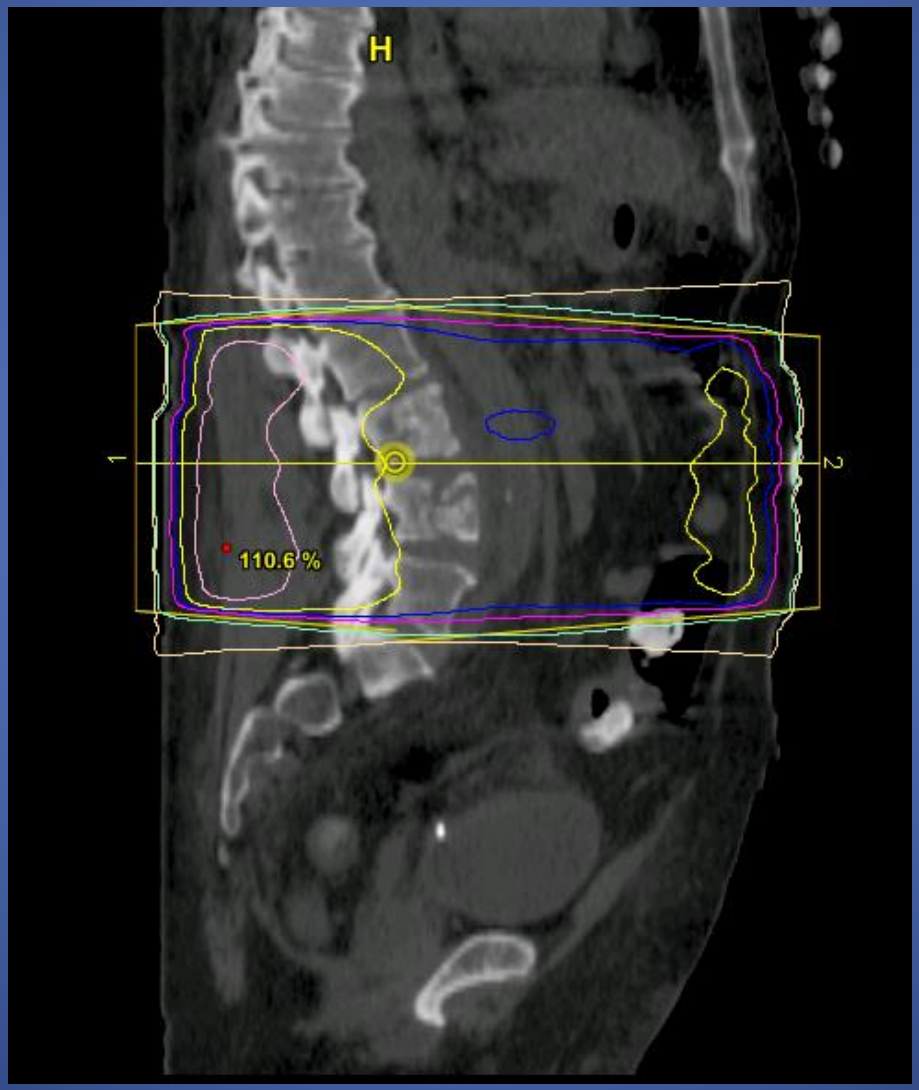
Radiation Oncology Terminology: Treatment Techniques

- 2D
- 3D CRT
- IMRT, VMAT
- Adaptive RT
- SRS
- SBRT, SABR
- TBI
- Brachytherapy
- …. and many others

Conventional 2D Planning

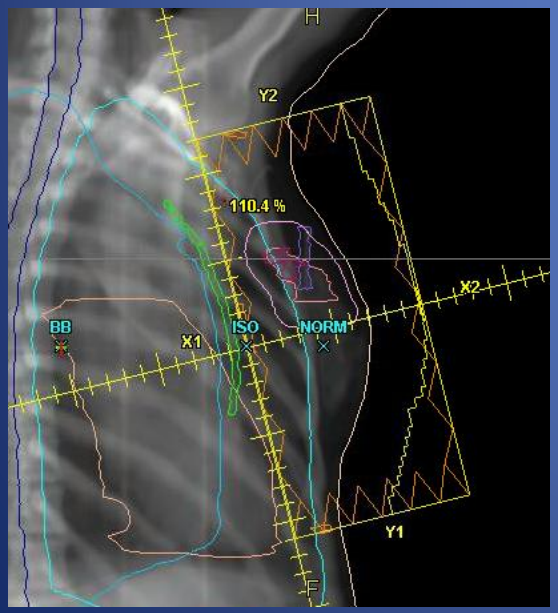


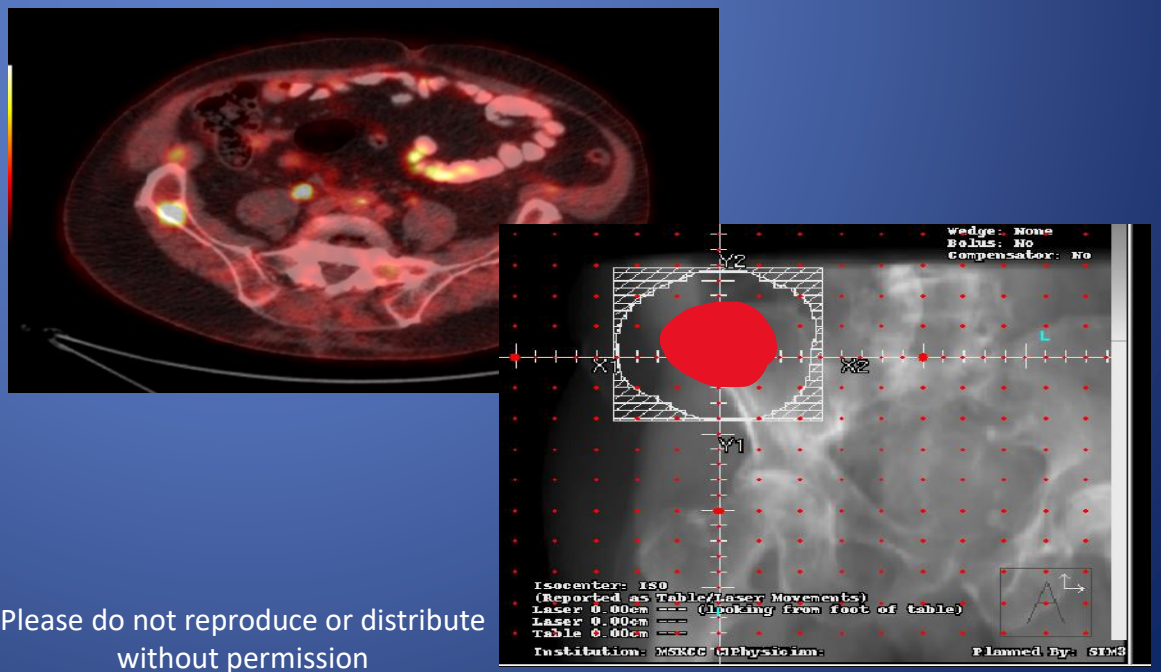
Conventional 2D Planning



3D Planning

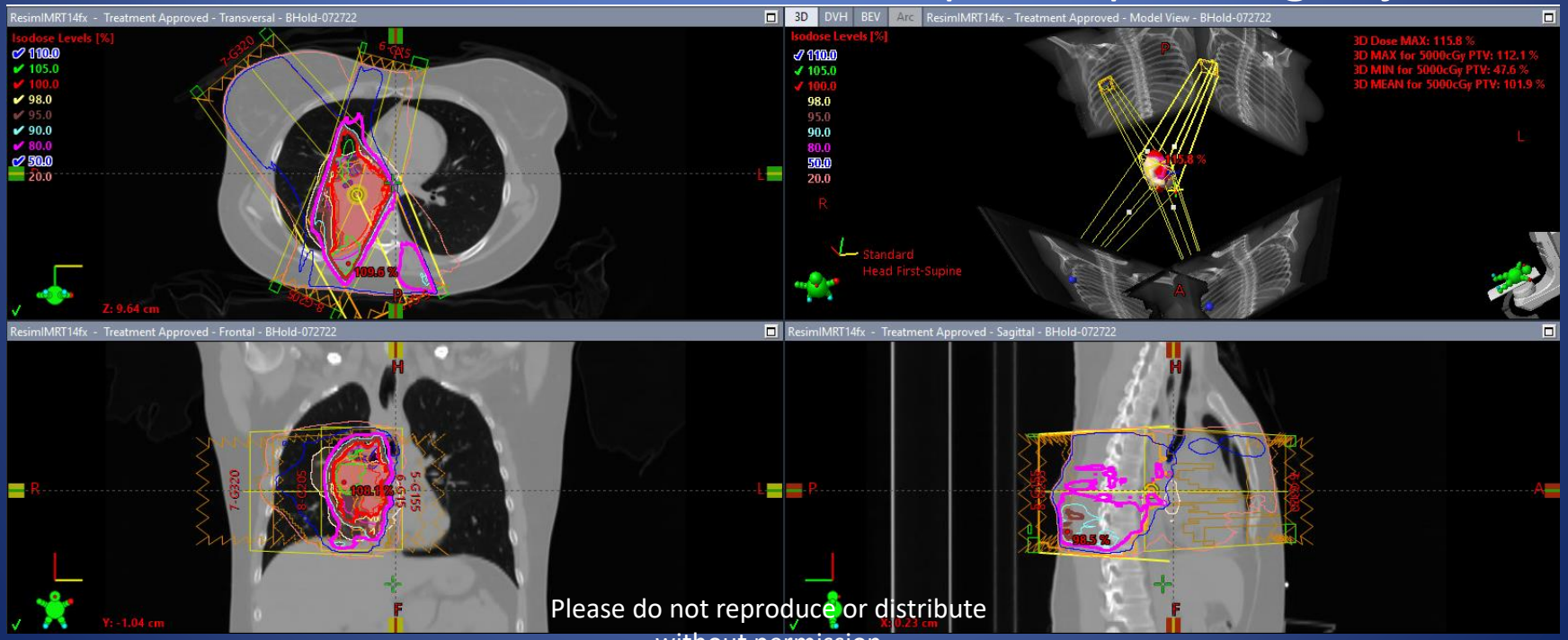
- **3D Conformal Radiation Therapy (3D CRT)**
  - Uses volumetric data from the planning imaging to conform the treatment fields to the targets and spare normal tissues



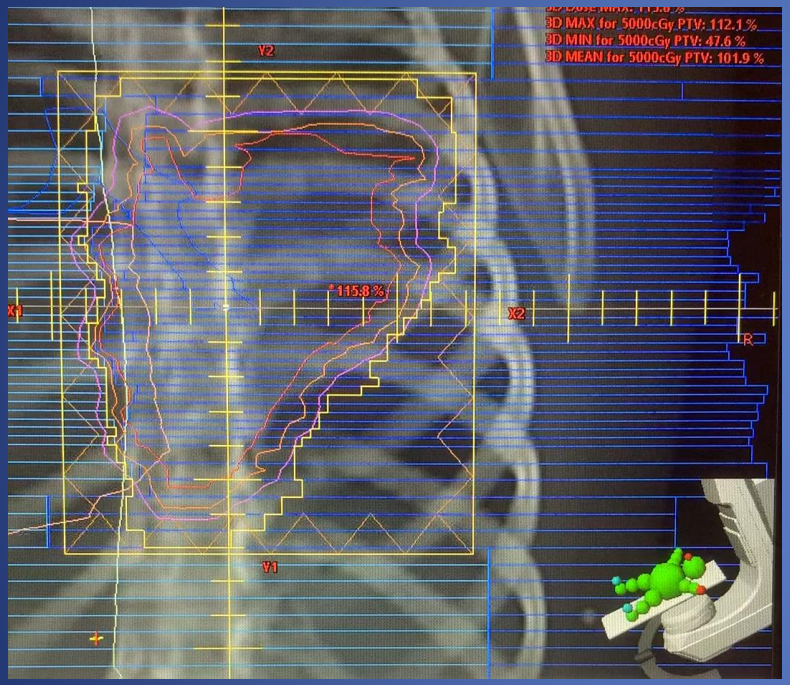


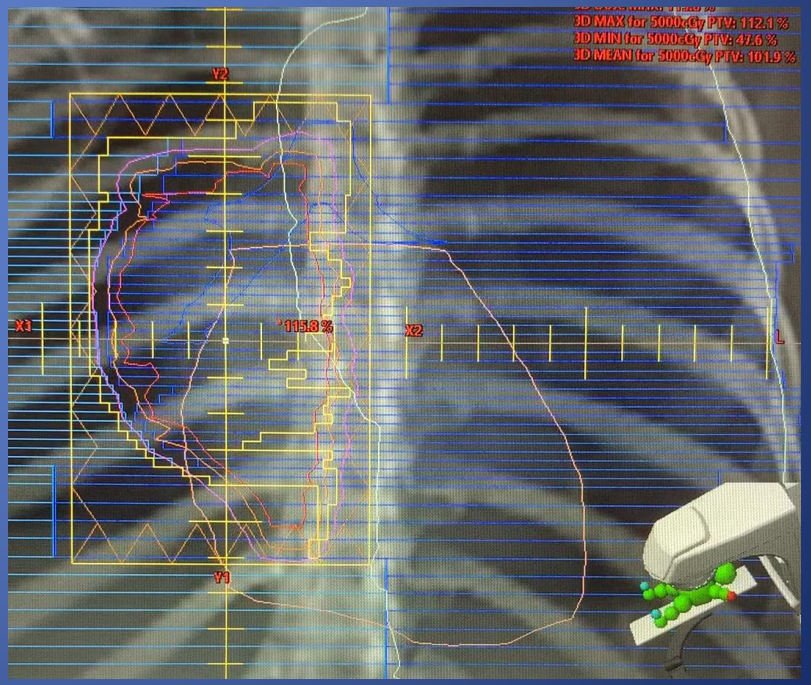
Static Field IMRT

- **Intensity-Modulated Radiation Therapy (IMRT)**
  - Modulation of the intensity across each beam
  - Allows customization based on a specific planning objective



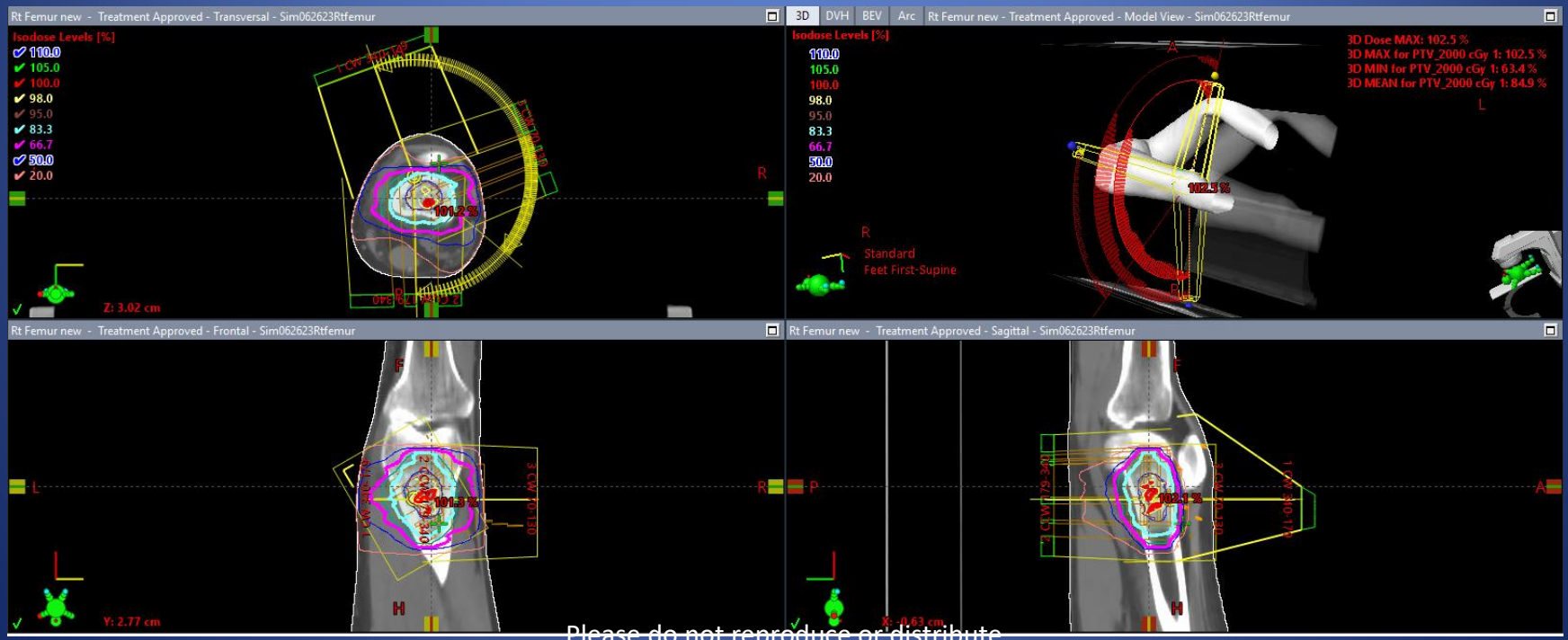
Static Field IMRT and moving MLCs



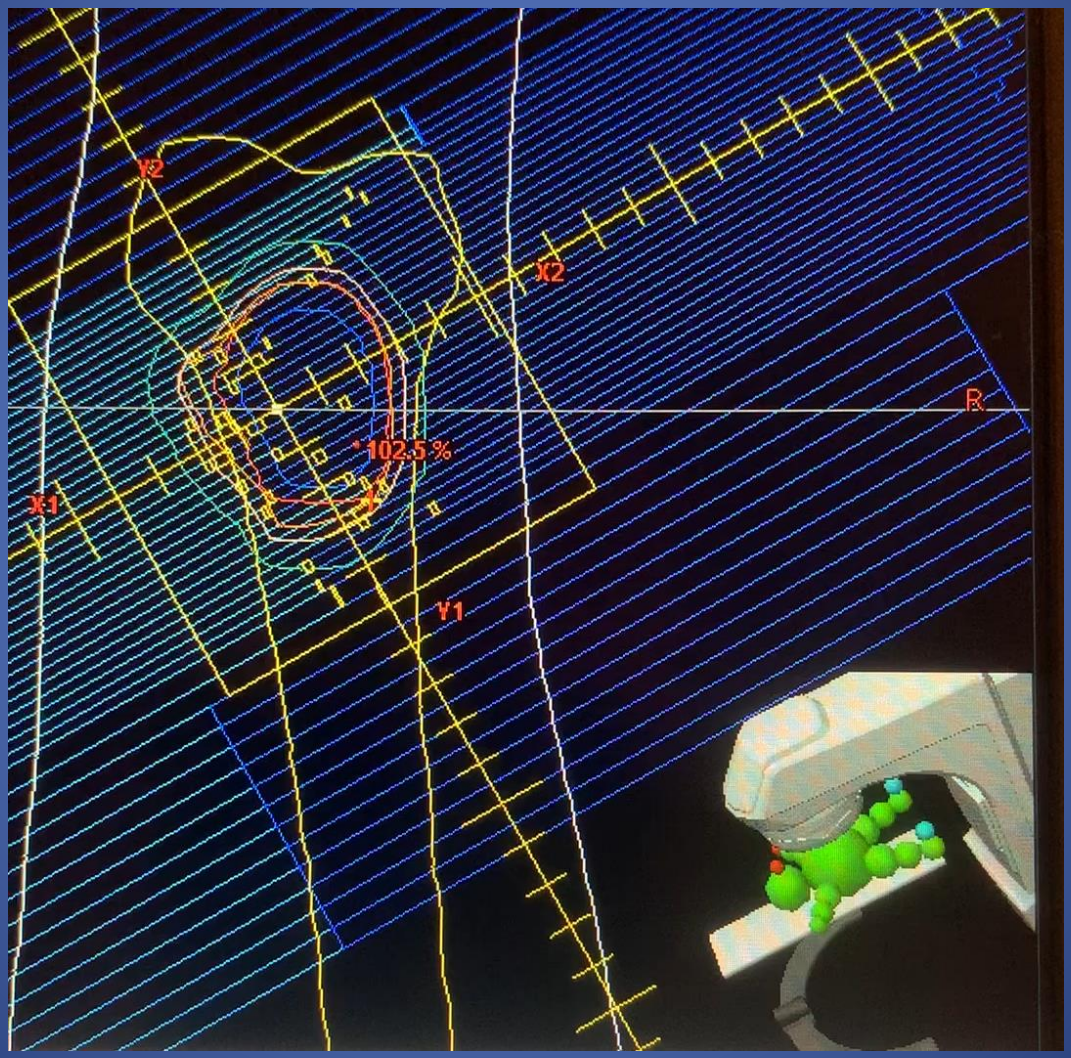


Partial Arc VMAT

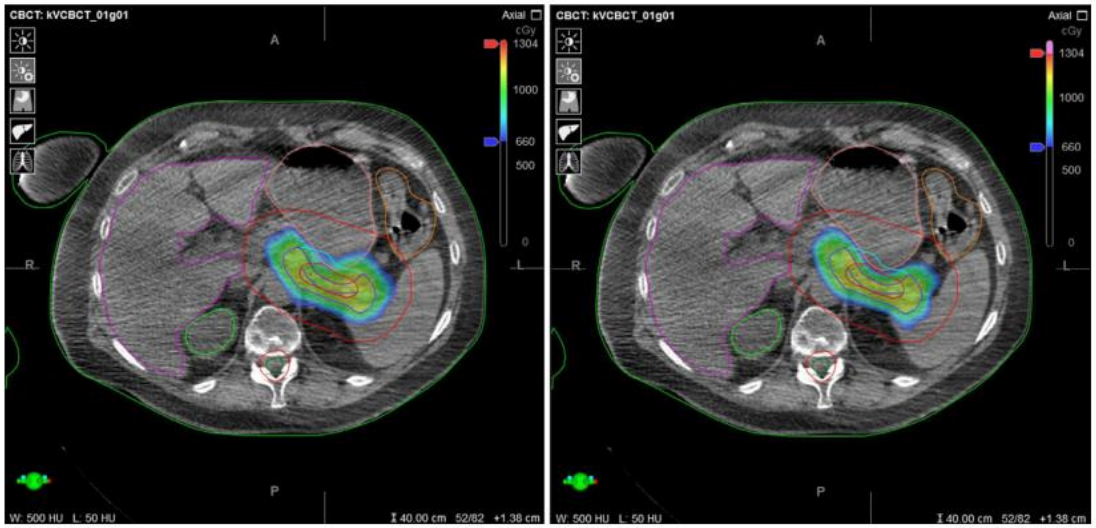
- **Volumetric Modulated Arc Therapy (VMAT)**
  - Modulation of the intensity across the beam
  - Gantry is moving as the MLCs are moving

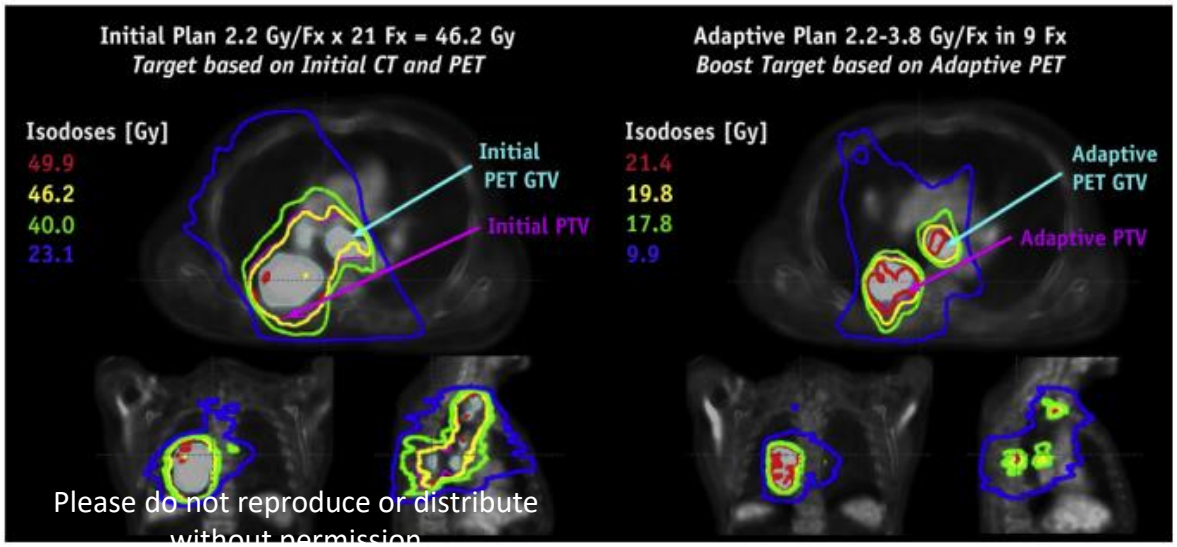


Partial Arc VMAT and moving MLCs



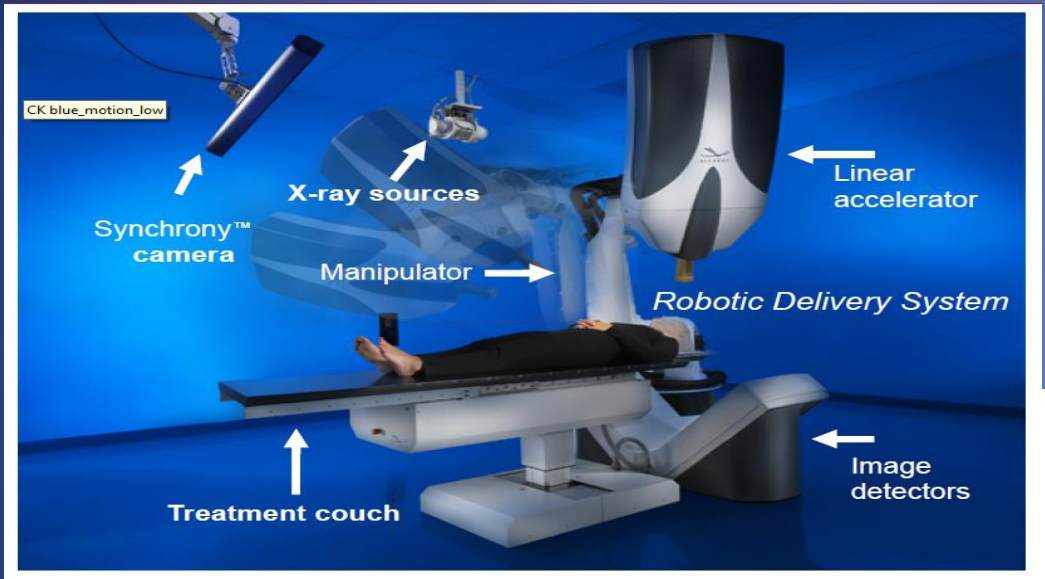
Adaptive Radiation Therapy (ART)



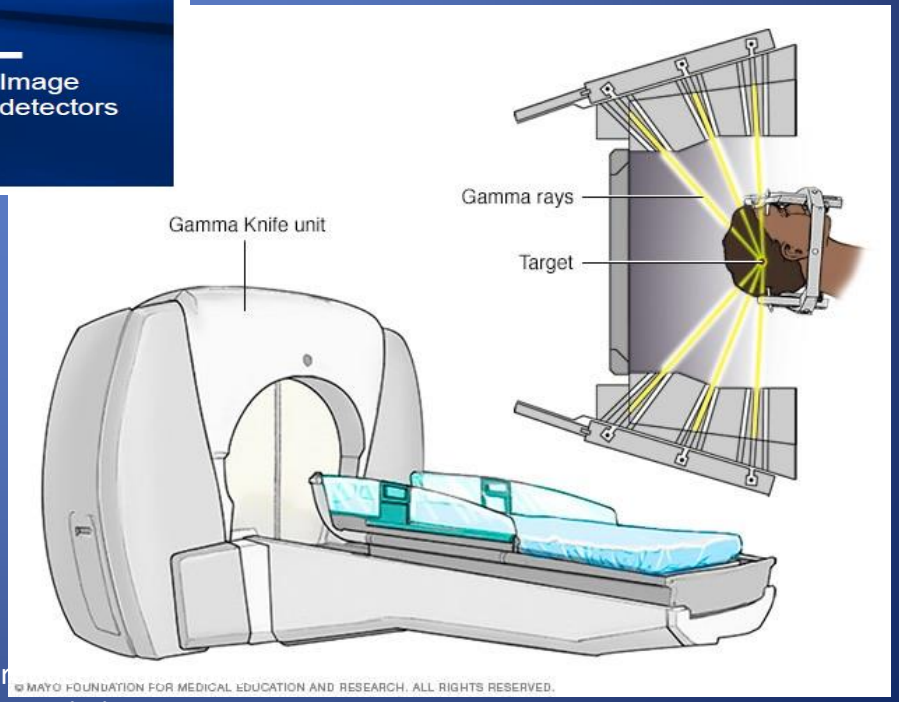


Kim et al PRO 2022
Glide-Hurst et al IJROBP 2021

Stereotactic Radiosurgery (SRS)



CyberKnife

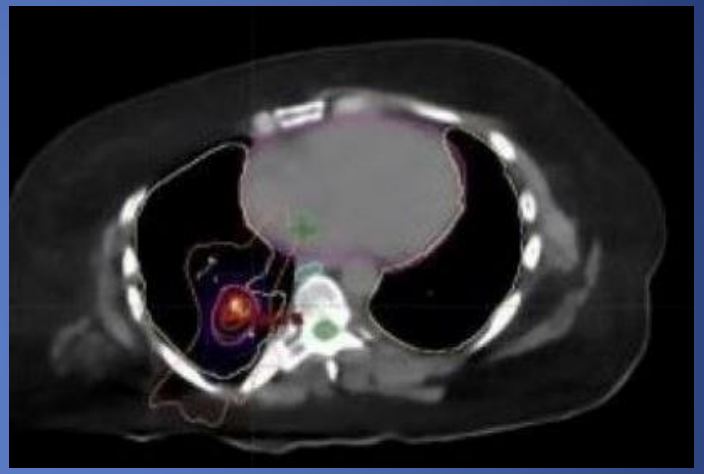


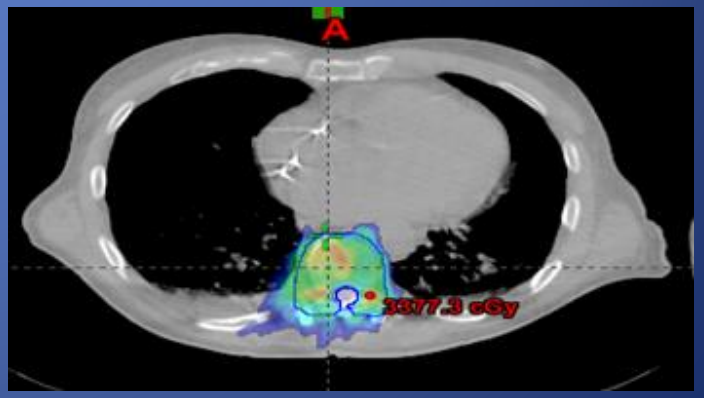
Gamma Knife

SRS can also be delivered on a LINAC

SBRT / SABR

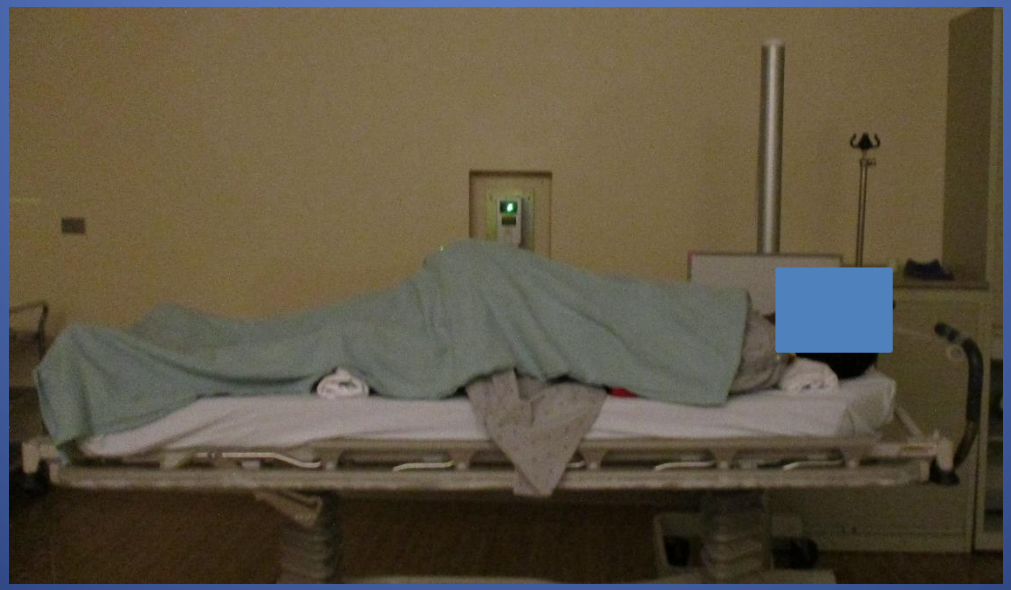
- **Stereotactic Body Radiation Therapy (SBRT)**
- **Stereotactic Ablative Body Radiotherapy (SABR)**





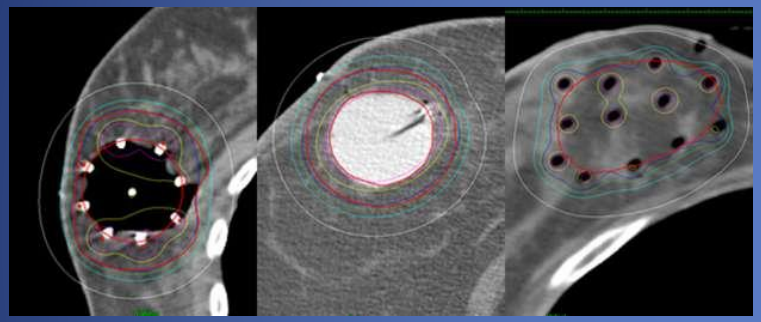
Total Body Irradiation (TBI)

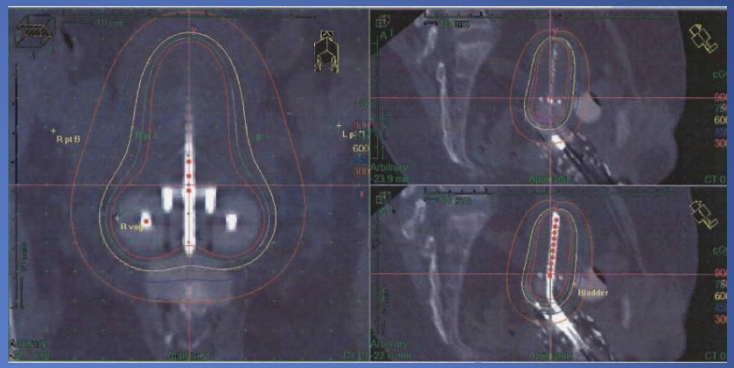
- Preparative regimen for transplant
- Leukemia and lymphoma
- At NIH, many protocols for non-malignant disease



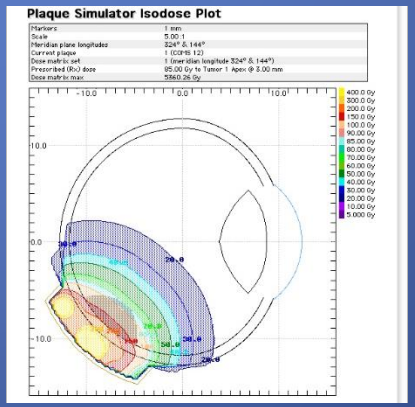
Brachytherapy

Interstitial and Intracavitary





Plaque



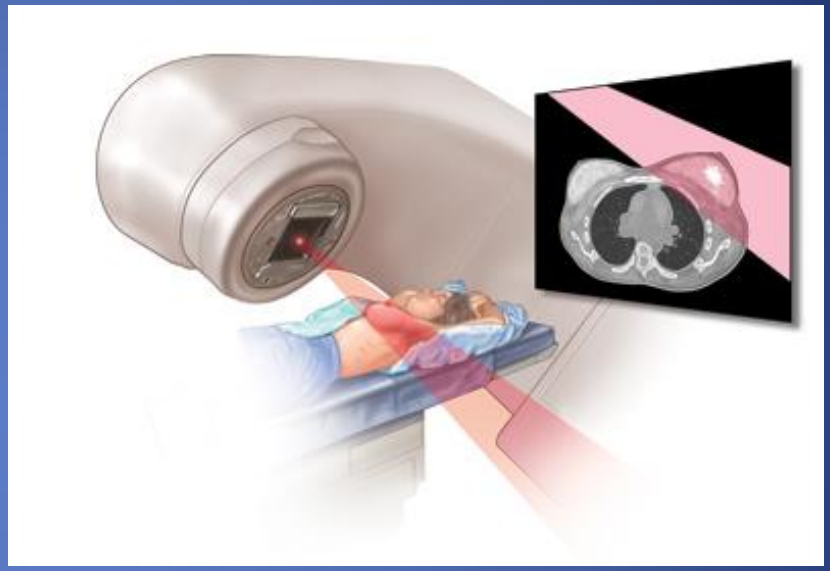
Seeds

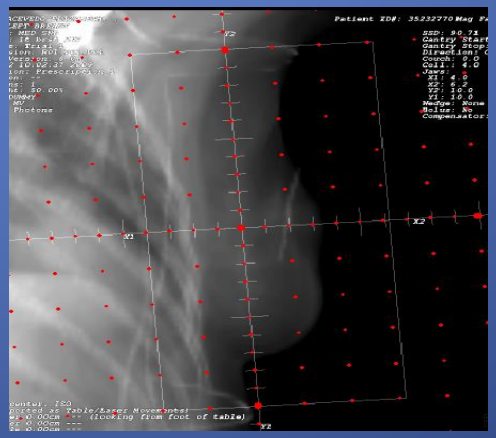
Treatment Set-up and Delivery

- Set-up verification
  - Treatment position, set up, and fields verified with imaging
  - Physician review and approval prior to treatment
  - Clinical, X-rays (kV and MV), CBCT, MRI

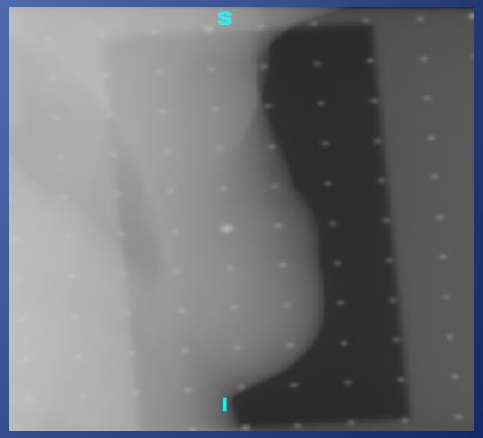
Set Up Verification: Port Films

- Films of the treatment fields are taken to verify set-up, field design, and blocking



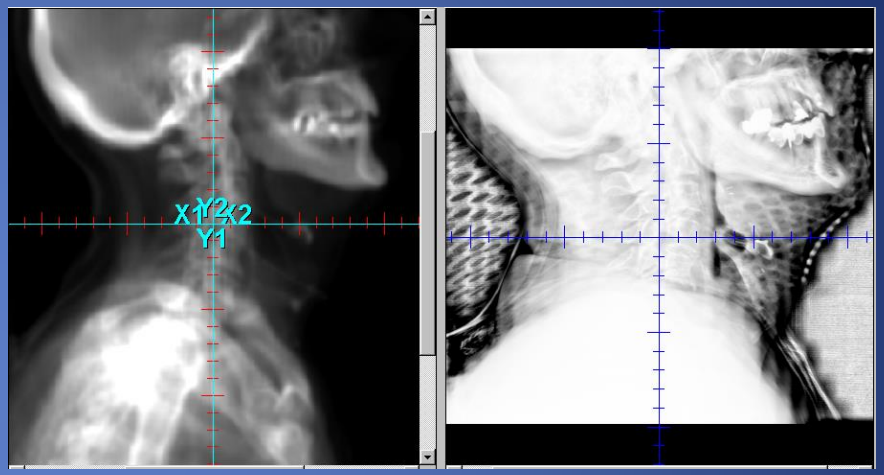


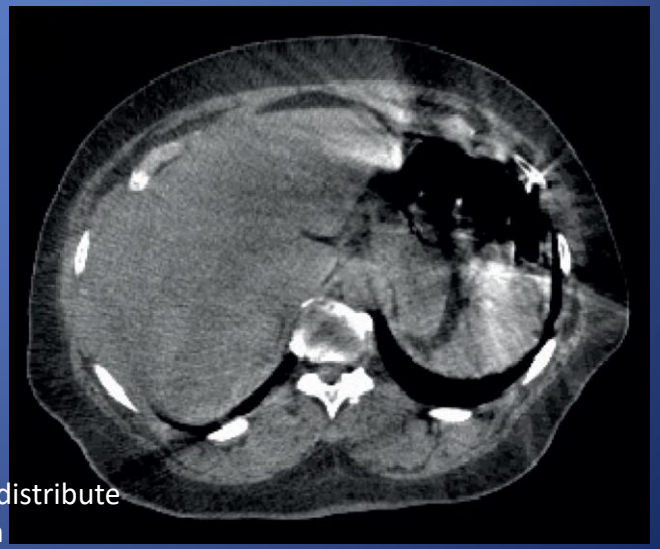
DRR/Sim Film

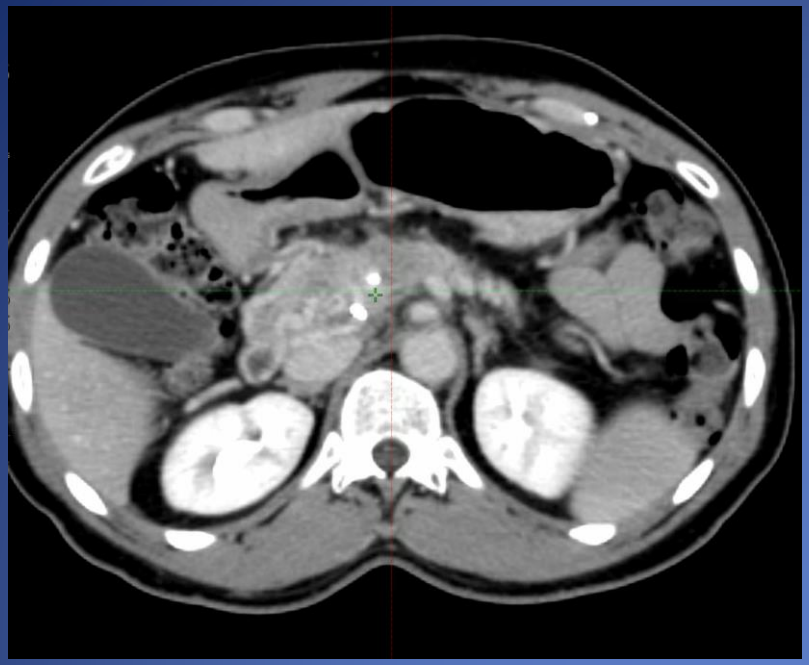


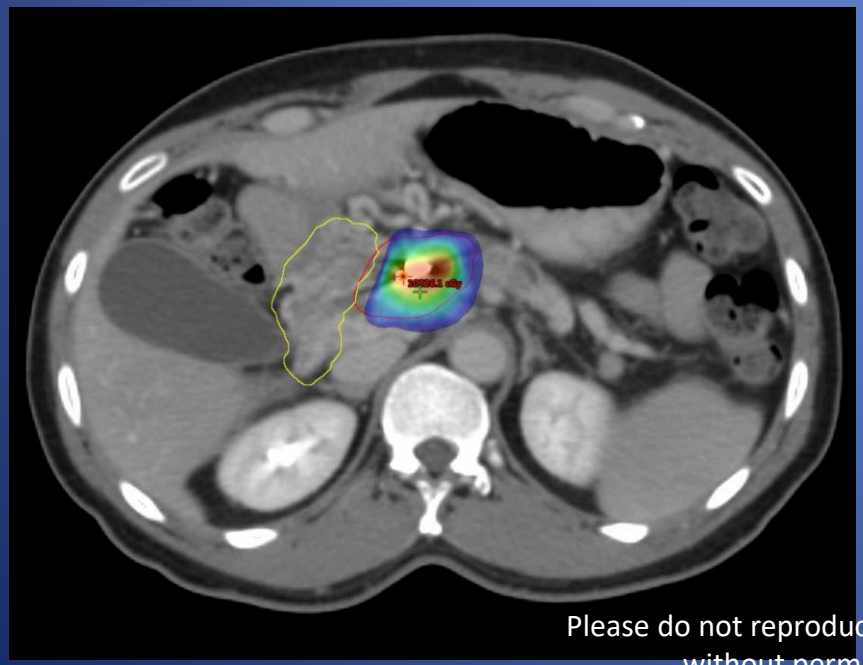
Portal film

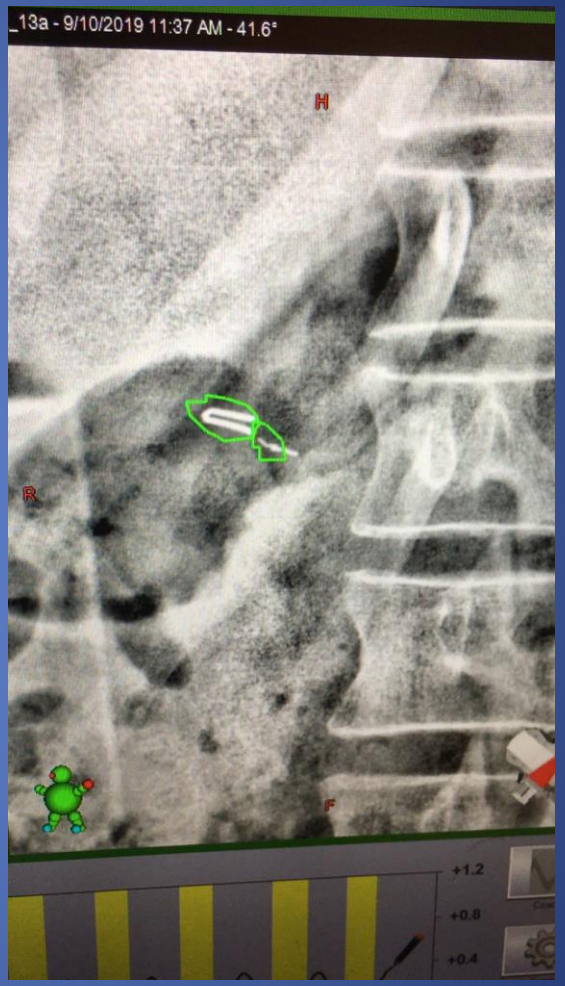
Image Guided Radiation Therapy (IGRT)











MRI-Guided RT

Weill Cornell Medicine

Video credit and thanks to Dr. Himanshu Nagar

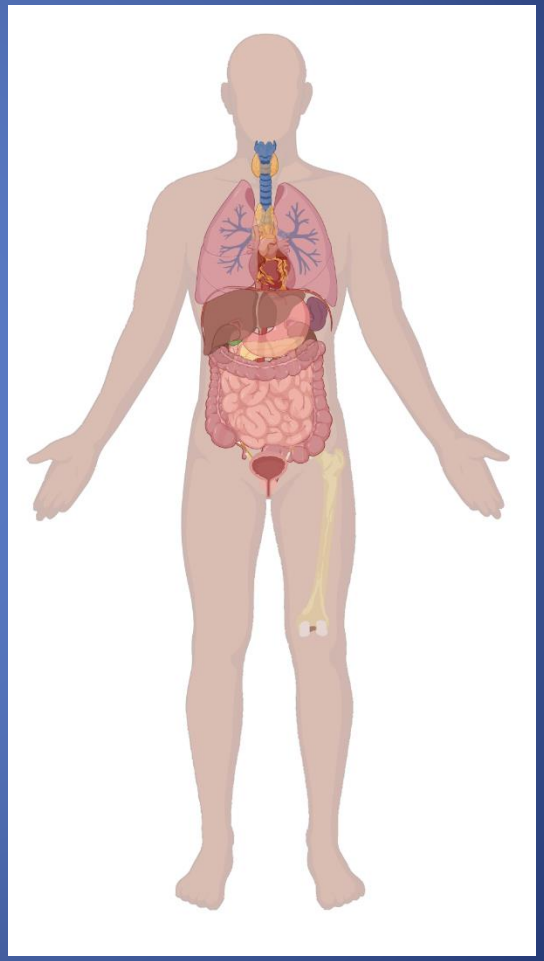
NewYork-Presbyterian

Treatment Delivery

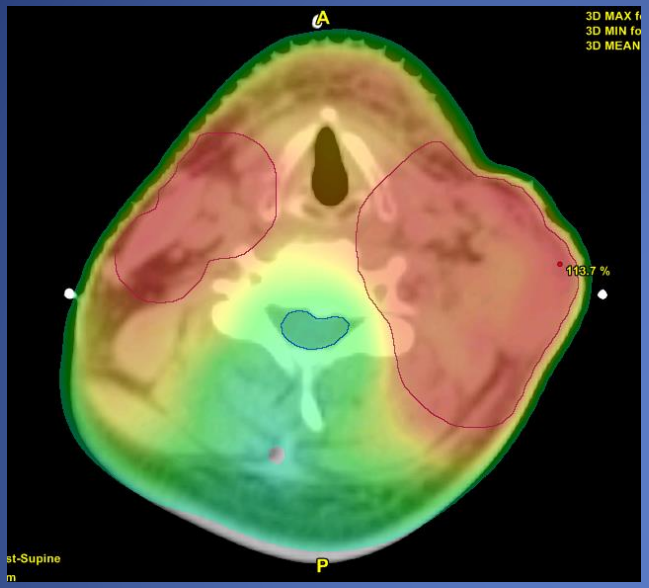
- Treatment delivery
  - RT usually given daily Monday-Friday
  - Some courses given every other day, twice daily, twice a week, etc.
  - Patients are seen for “on treatment visits” (OTVs) during RT
  - Assessment and management of toxicities

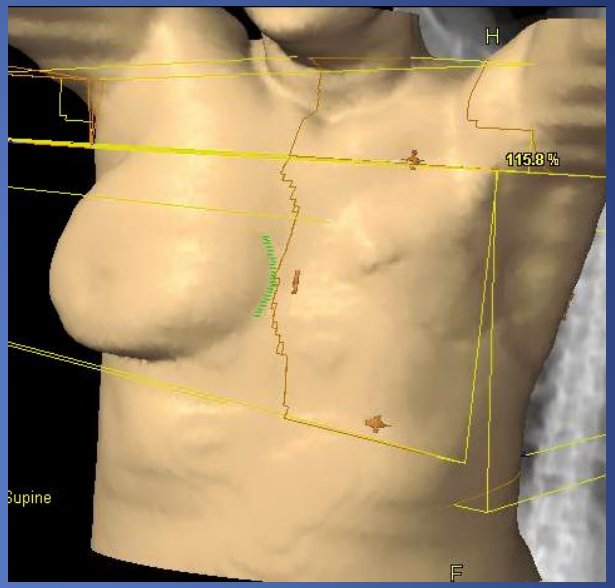
Acute and Late Toxicities of RT

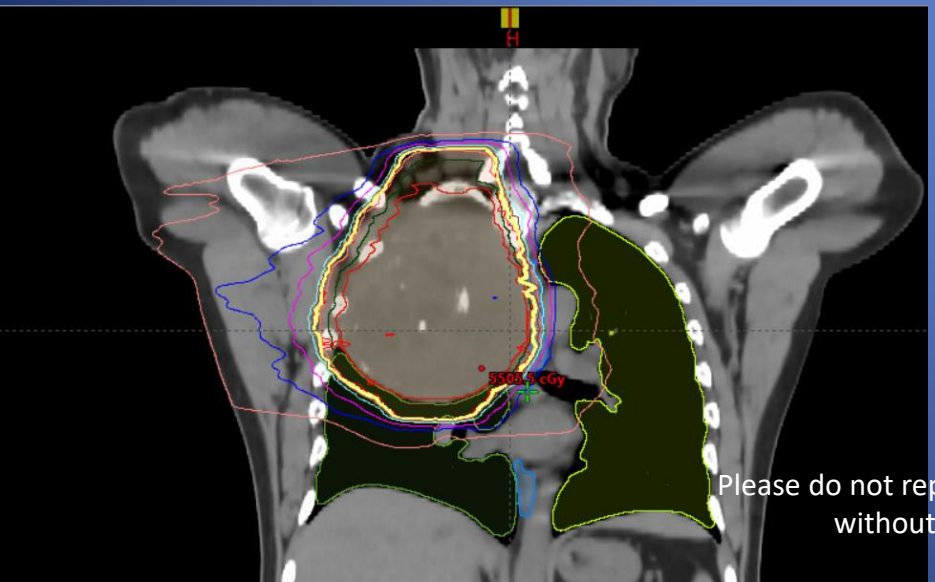
- Acute:
  - During and shortly after RT (days to weeks)
  - Generally reversible
  - Inflammatory
- Late:
  - Months to years after RT
  - Chronic and generally irreversible
  - Fibrosis

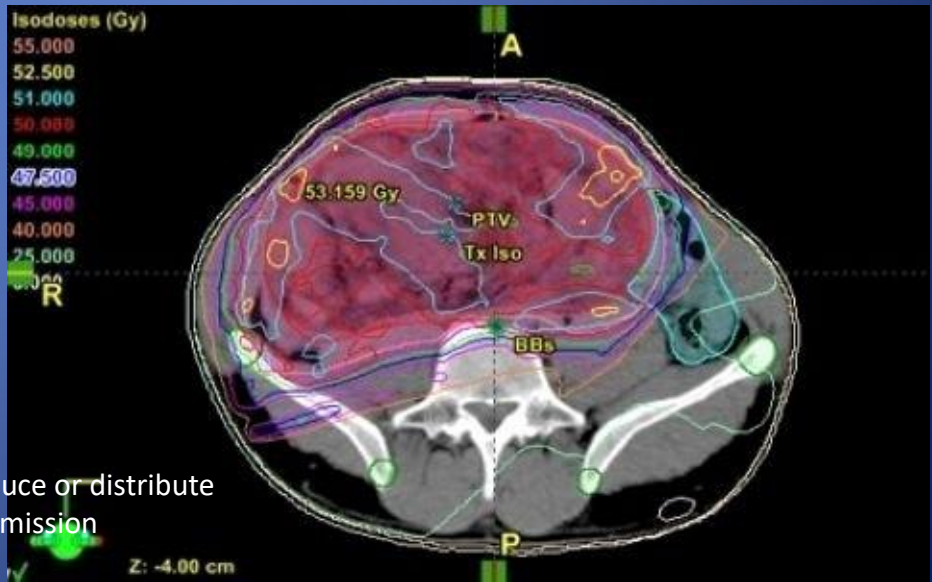


Acute and Late Toxicities of RT

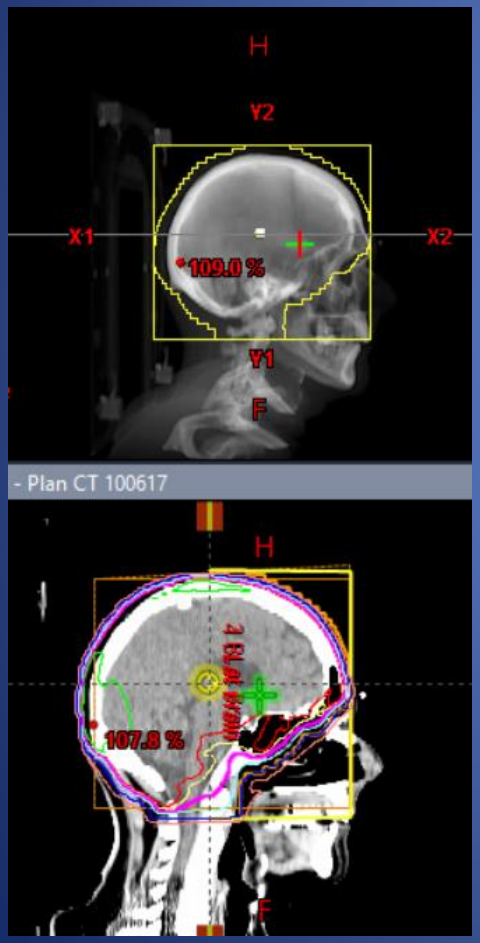


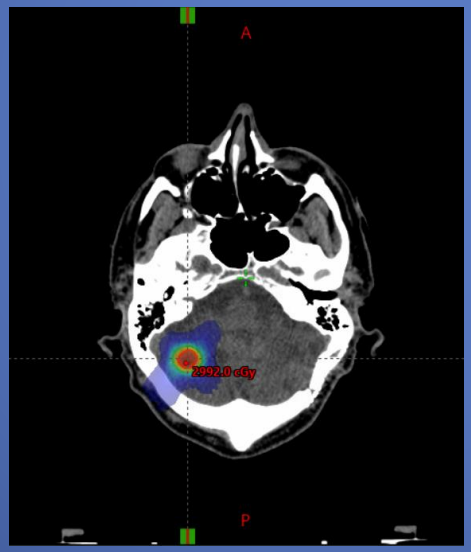


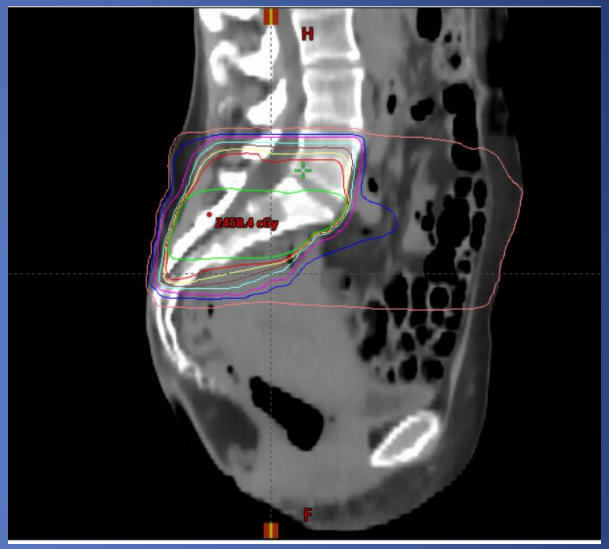




Acute and Late Toxicities of RT







Acute and Late Toxicities of RT

- Secondary Malignancies
  - Radiation associated malignancies
  - Rare, risk is small but non-zero
  - Latency period
  - Distinct from initial cancer
  - Other contributing risk factors

Introduction to Radiation Oncology

- Indications for emergent/urgent RT
  - Spinal cord compression/cauda equina syndrome
  - Brain metastases
  - Obstruction
  - SVC syndrome
  - Bleeding
  - Intractable pain
  - Anything deemed so…

Introduction to Radiation Oncology

- What radiation oncologists want to know when you call for urgent consults (or any consult)?
  - **Any prior radiation therapy?**
    - Need radiation treatment summary or completion note
  - Any implanted electronic medical devices?
  - Most recent imaging?

Overview of ROB

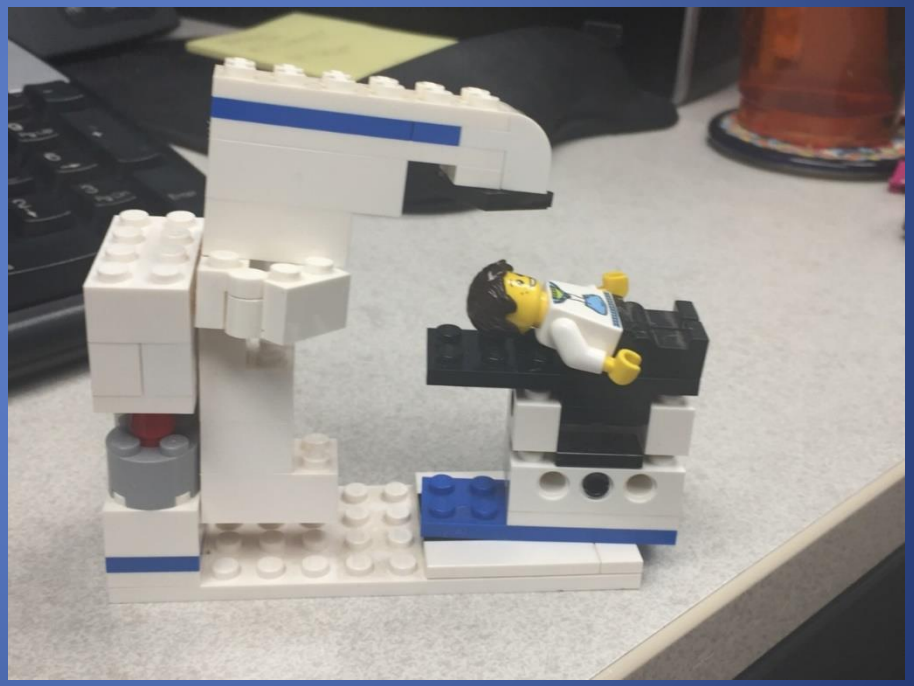
- How to reach us:
  - Doc of the day covering each clinic day
  - Radiation oncologist on call
  - Call the ROB clinic
  - Call or email me
  - Can reach out to Tess or Debbie

Thank You

Thanks to Dr. Michael Mix, Dr. Lindsay Rowe, and Dr. Freddy Escorcia for their shared slides that have been adapted and used.

Thanks to Dr. Himanshu Nagar for the shared MRI-guided RT video that has been adapted and used.

Happy to answer questions.



kilian.salerno@nih.gov