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Introduction to Radiation Oncology

What Every Medical Student Needs to Know

ASSOCIATION OF RESIDENTS IN RADIATION ONCOLOGY ARRO

Objectives

- Introduction to Oncology
  - Epidemiology
- Overview
  - Mechanism of Action
- Production of Radiation
- Delivery of Radiation
- Definitive vs Palliative Therapy
- Dose and Fractionation
- Process of Radiation
- MCW Radiation Oncology Department

Medical Student Goals

- Introduction to oncology basics
- Learn basics of radiation oncology
- Attend Tumor Board and conferences
- Have Fun!

Cancer Epidemiology [5]

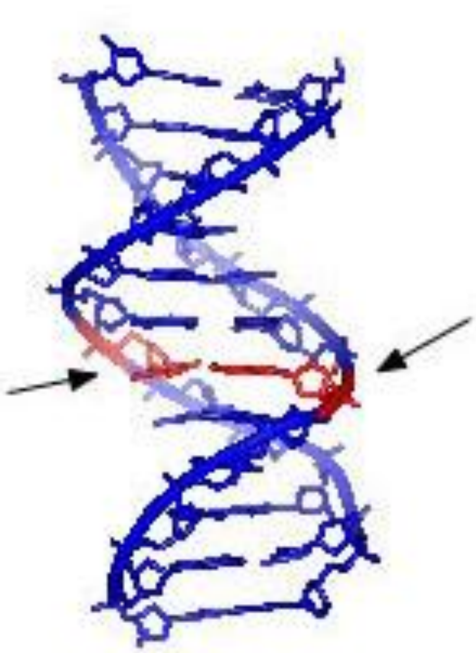
- Uncontrolled growth and spread of abnormal cells
  - If the spread is not controlled, it can result in death
- Approximately 1,660,290 new cancer cases are expected to be diagnosed in 2013

Introduction to Radiation [1]

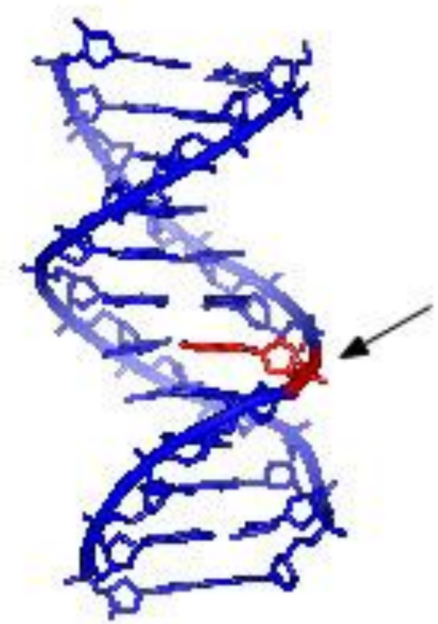
- Radiation oncology is the medical use of ionizing radiation (IR) as part of cancer treatment to control malignant cells.

- IR damages DNA of cells either directly or indirectly, through the formation of free radicals and reactive oxygen species.

Mechanism of IR [4]



Double-Stranded Break



Single-Stranded Break

RT-Induced Cell Death[4]

- Mitotic cell death
  - Double and single-stranded breaks in a cell's DNA prevent that cell from dividing.

- Direct cell killing through apoptosis

Normal Cells vs Cancer Cells[4]

- Cancer cells are usually undifferentiated and have a decreased ability to repair damage
  - Healthy (normal) cells are differentiated and have the ability to repair themselves (cell cycle check points)
    - G0→G1→S→G2→M

- DNA damage in cancer cells is inherited through cell division
  - accumulating damage to malignant cells causes them to die

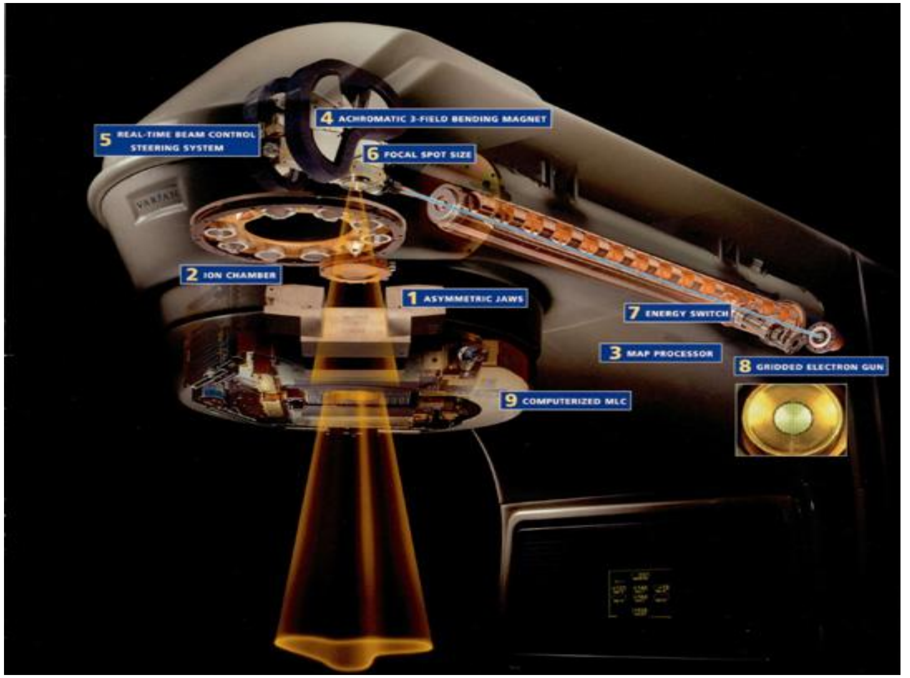
Production of Radiation[1]

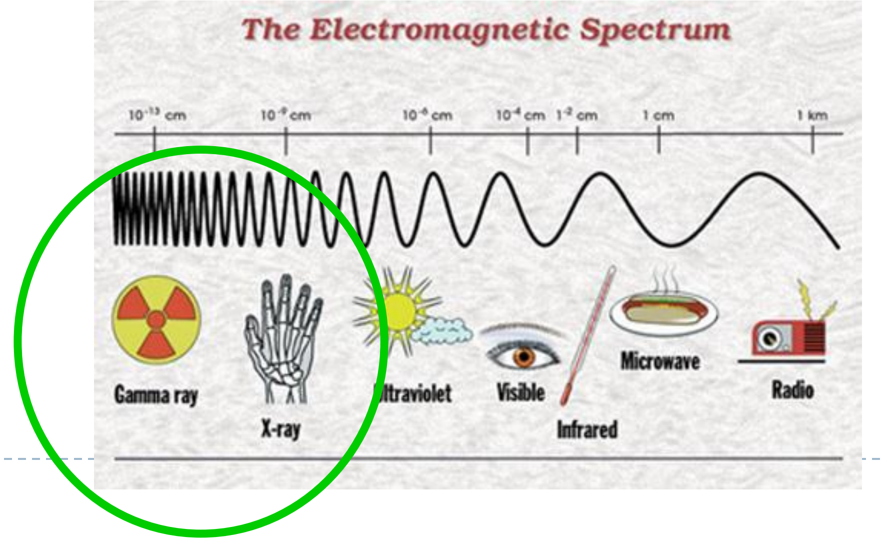
- IR is produced by electron, photon, proton, neutron or ion beams

- Beams are produced by linear accelerators (LINAC)

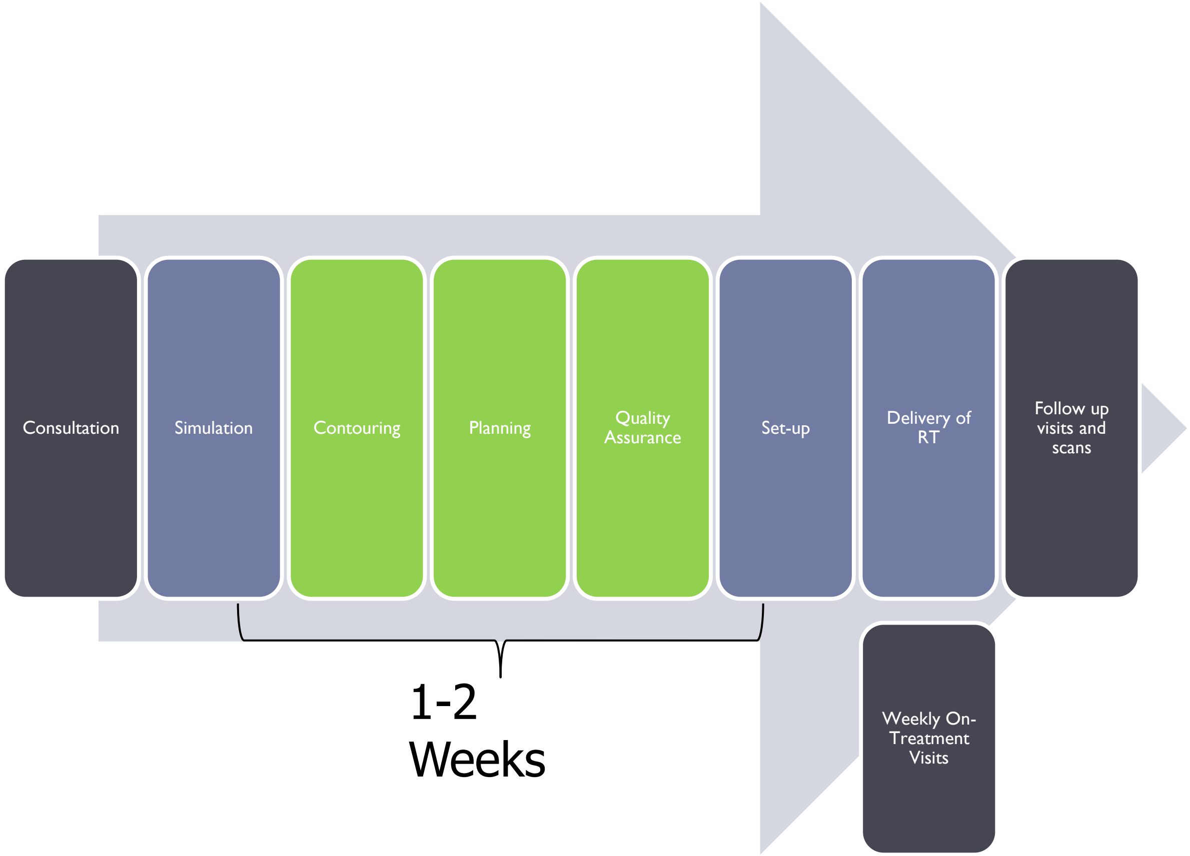
Three Main Types of External Beam

- Photons
  - X-rays from a linear accelerator
- Light Charged Particles
  - Electrons
- Heavy Charged Particles
  - Protons
  - Carbon ions





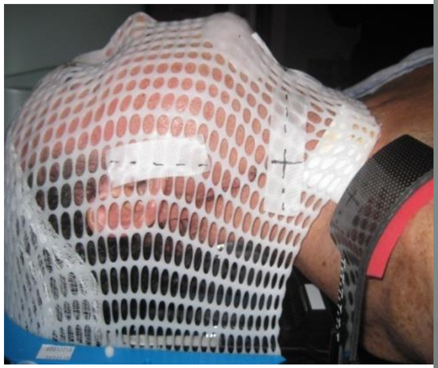
Timeline

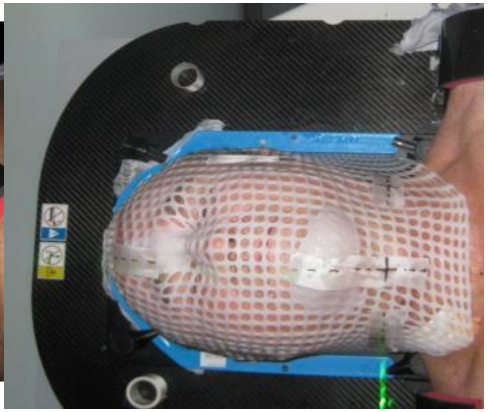


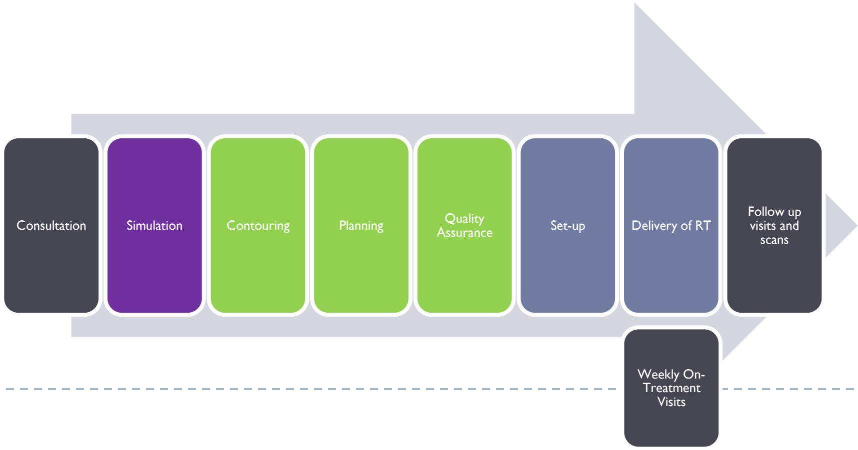
Consultation
Simulation
Contouring
Planning
Quality Assurance
Set-up
Delivery of RT
Follow up visits and scans
Weekly On-Treatment Visits
1-2 Weeks

What is a simulation?

- Custom planning appointment placing patient in reproducible position

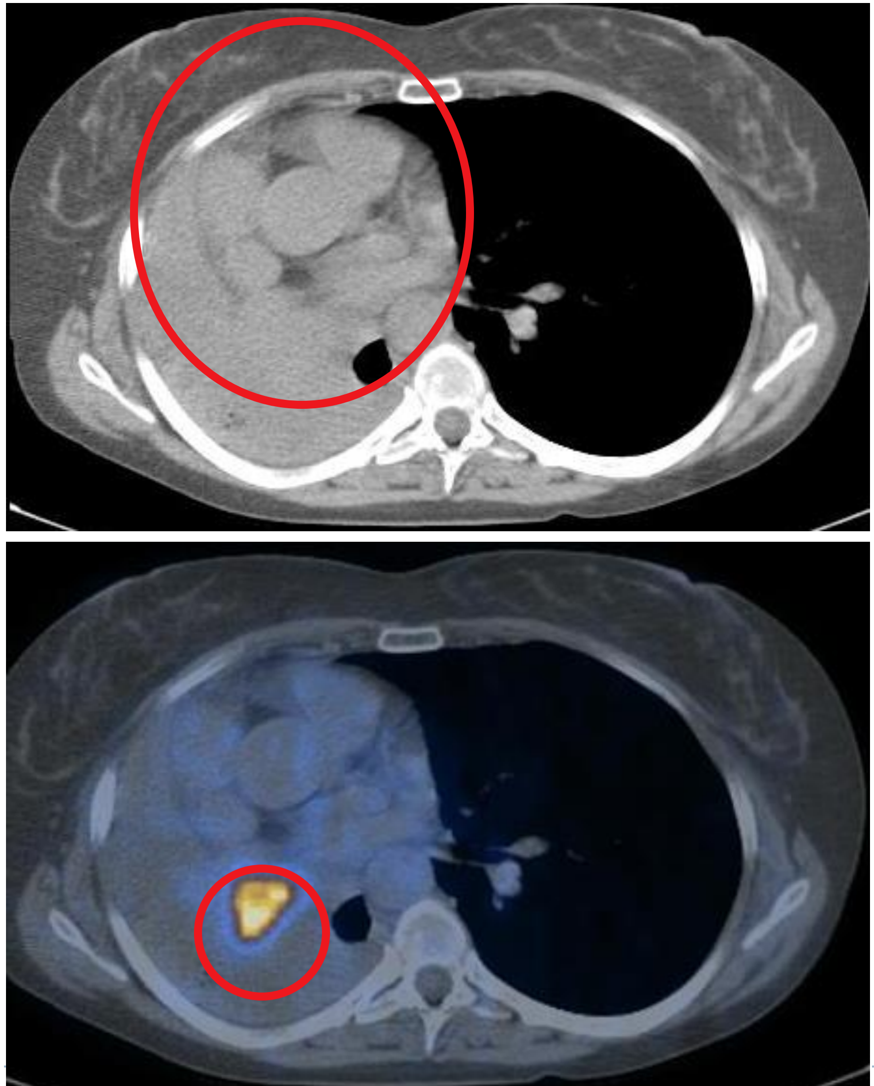




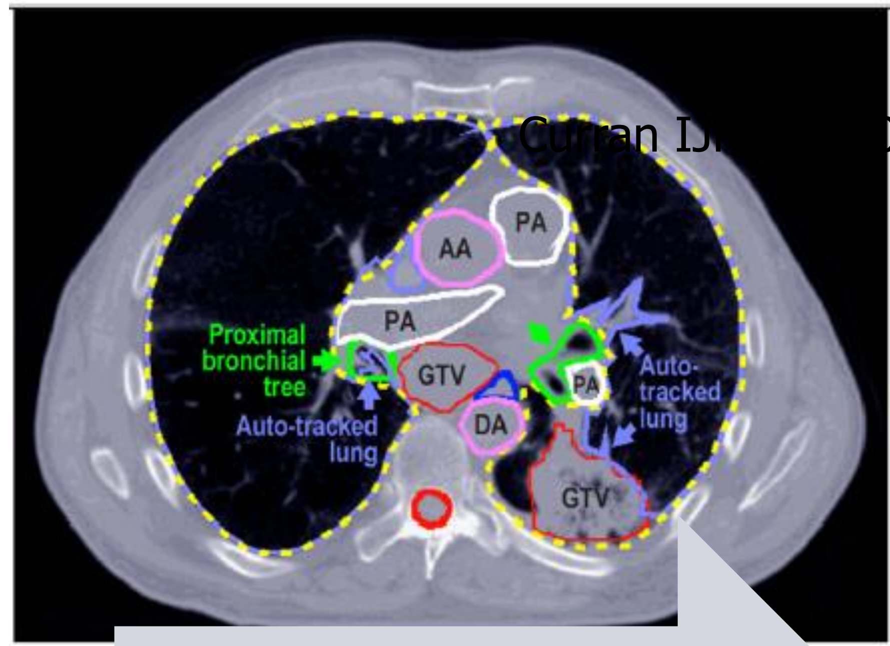


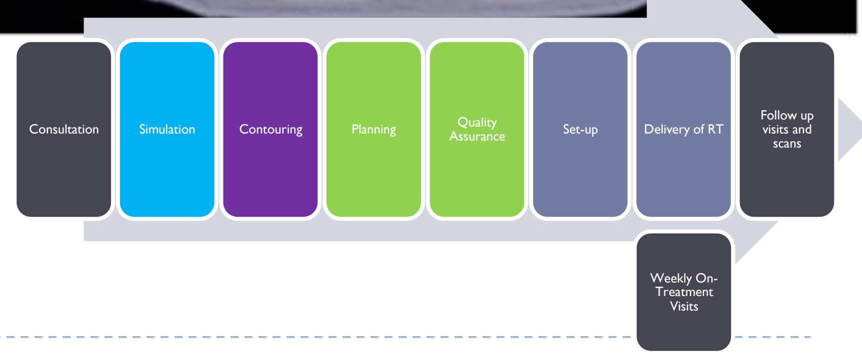
Contouring: Advances in Simulation Imaging Really Help!

PET/CT simulation



- Target structures
- Organs at risk (OARs) aka normal tissues





Curran et al.

Linear Accelerator (LINAC) [1]

- Delivers a uniform dose of high-energy X-rays to the tumor.
- X-rays can kill the malignant cells while sparing the surrounding normal tissue.
  - Treat all body sites with cancer
- LINAC accelerates electrons, which collide with a heavy metal target→ high-energy X-rays are produced.
- High energy X-rays directed to tumor
  - X-rays are shaped as they exit the machine to conform to the shape of the patient's and the tumor.

LINAC[1]

- Conformal treatment
  - Blocks placed in the head of the machine
  - Multileaf collimator that is incorporated into the head of the machine.
  - The beam comes out of the gantry, which rotates around the patient.
- Pt lies on a moveable treatment table and lasers are used to make sure the patient is in the proper position.
- RT can be delivered to the tumor from any angle by rotating the gantry and moving the treatment couch.

http://www.varian.com/media/oncology/products/clinac/images/clinac_2100c.jpg

http://www.varian.com/media/oncology/products/clinac/images/Stanford270_crop_Web.jpg

Delivery of Radiation[1,4]

- External beam RT (outside body)
  - Conventional 3D-RT (using CT based treatment planning)

  - Stereotactic radiosurgery
    - Ffocused RT beams targeting a well-defined tumor using extremely detailed imaging scans.
      - Cyberknife
      - Gamma Knife
      - Novalis
      - Synergy
      - TomoTherapy

Gamma Knife[6]

- Device used to treat brain tumors and other conditions with a high dose of RT in 1 fraction.
- Tumors or tumor cavities ≤ 4 cm
- Contains 201 Co-60 sources arranged in a circular array in a heavily shielded device.
  - This aims gamma RT through a target point in the pt's brain.
- Halo surgically fixed to skull for immobilization
- MRI done → used for planning purposes.
- Ablative dose of RT is then sent through the tumor in 1 fraction
  - Surrounding brain tissues are relatively spared.
- Total time can take up to 45 minutes

Gamma Knife

http://local.ans.org/virginia/meetings/2004/GammaKnifePatientSmall.jpeg

- Intensity Modulated Radiotherapy (IMRT)
  - High-precision RT that improves the ability to conform the treatment volume to concave tumor shapes
- Image-Guided RT (IGRT)
  - Repeated imaging scans (CT, MRI or PET) are performed daily while pt is on treatment table.
  - Allows to identify changes in a tumor's size and/or location and allows the position of the patient or dose to be adjusted during treatment as needed.
  - Can increase the accuracy of radiation treatment (reduction in the planned volume of tissue to be treated)→ decrease radiation to normal tissue

- Tomotherapy
  - Form of image-guided IMRT
    - Combination of CT imaging scanner and an external-beam radiation therapy machine.
    - Can rotate completely around the patient in the same manner as a normal CT scanner.
- Obtain CT images of the tumor before treatment→ precise tumor targeting and sparing of normal tissue.

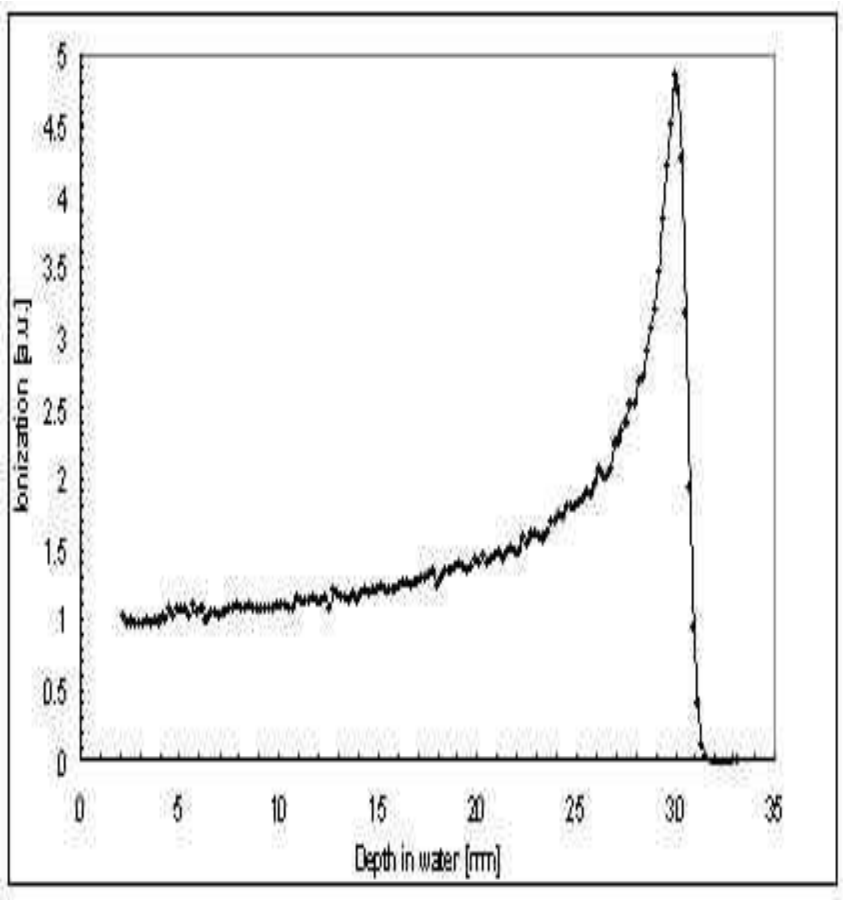
Tomotherapy

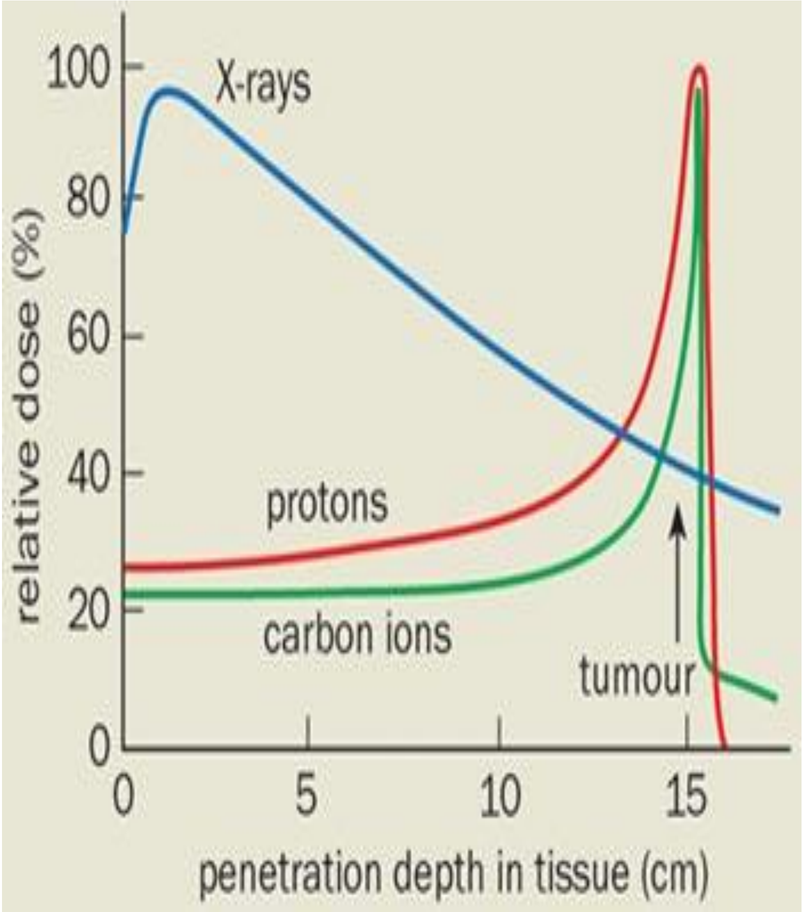
http://www.mcw.edu/FileLibrary/Groups/RadiationOncology/images/Tomo.jpg

Proton Therapy

- Protons are positively charged particles located in the nucleus of a cell.
- Deposit energy in tissue differently than photons
  - Photons: Deposit energy in small packets all along their path through tissue
  - Protons deposit much of its energy at the end of their path
    - Bragg peak (see next slide)

Bragg Peak





http://web2.lns.infn.it/CATANA/images/News/toppag1.jpg

http://images.iop.org/objects/phw/world/16/8/9/pwhad2_08-03.jpg

Brachytherapy

- Sealed radioactive sources placed in area of treatment
- Low dose (LDR) vs High Dose (HDR)
  - LDR: Continuous low-dose radiation from the source over a period of days
  - Ex) Radioactive seeds in prostate cancer
- HDR: Robotic machine attached to delivery tubes placed inside the body guides radioactive sources into or near a tumor.
  - Sources removed at the end of each treatment session.
  - HDR can be given in one or more treatment sessions.
  - Ex. Intracavitary implants for gynecologic cancer

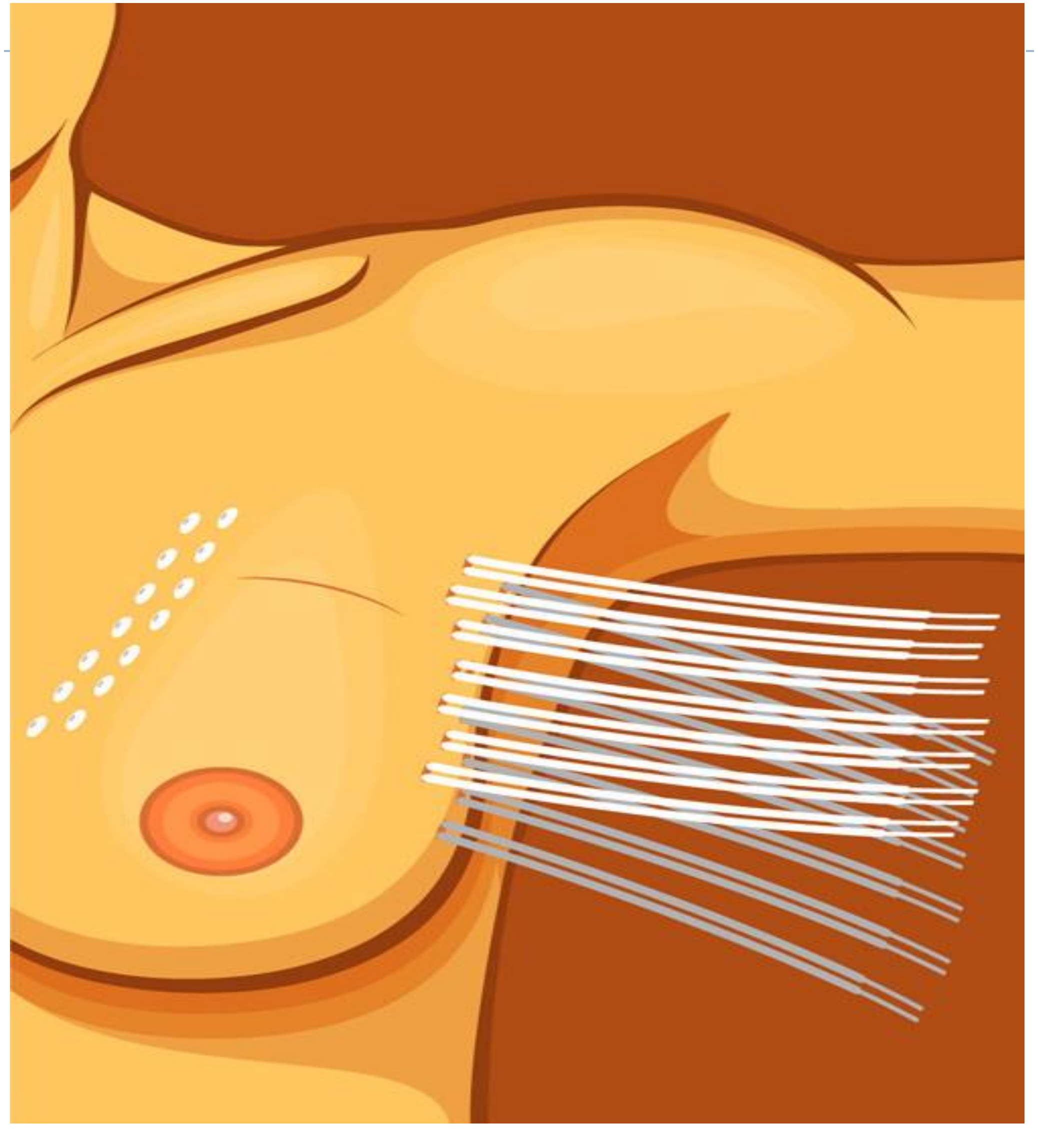
- Temporary vs. Permanent Implants
  - Permanent: Sources are surgically sealed within the body and remain there after radiation delivered
  - Example: Prostate seed implants (see next slide)

Prostate Seed Implants

http://roclv.com/img/treatments/brachytherapy-245.jpg

- Temporary: Catheters or other "carriers" deliver the RT sources (see next slide)
  - Catheters and RT sources removed after treatment.
  - Can be either LDR or HDR

Breast multi-catheter placement



http://kogkreative.com/009_BreastBrachy.JPG

Uses of RT[2]

- Definitive Treatment
  - Aid in killing both gross and microscopic disease
- Palliative Treatment
  - Relieve pain or improve function or in pts with widespread disease or other functional deficits
    - Cranial nerve palsies
    - Gynecologic bleeding
    - Airway obstruction.
- Primary mode of therapy
- Combine radiotherapy with surgery, chemotherapy and/or hormone therapy.

Dose[3]

- Amount of RT measured in gray (Gy)
  - Varies depending on the type and stage of cancer being treated.
  - Ex. Breast cancer: 50-60 Gy (definitive)
  - Ex. SC compression: 30 Gy (palliative)

- Dose Depends on site of disease and if other modalities of treatment are being used in conjunction with RT

- Delivery of particular dose is determined during treatment planning

Fractionation[3]

- Total dose is spread out over course of days-weeks (fractionation)
  - Allows normal cells time to recover, while tumor cells are generally less efficient in repair between fractions
  - Allows tumor cells that were in radio-resistant phase of the cell cycle during one treatment to cycle into a sensitive phase of the cycle before the next tx is given.
- RT given M-F/ 5 days per week.
  - For adults usually administer 1.8 to 2 Gy/day, depending on tumor type
- In some cases, can give 2 tx (2 fractions) per day

Radiosensitivity[3]

- Different cancers respond differently to RT

- Highly radiosensitive cancer cells are rapidly killed by modest doses of RT
  - Lymphomas (30-36 Gy)
  - Seminomas (25-30 Gy)

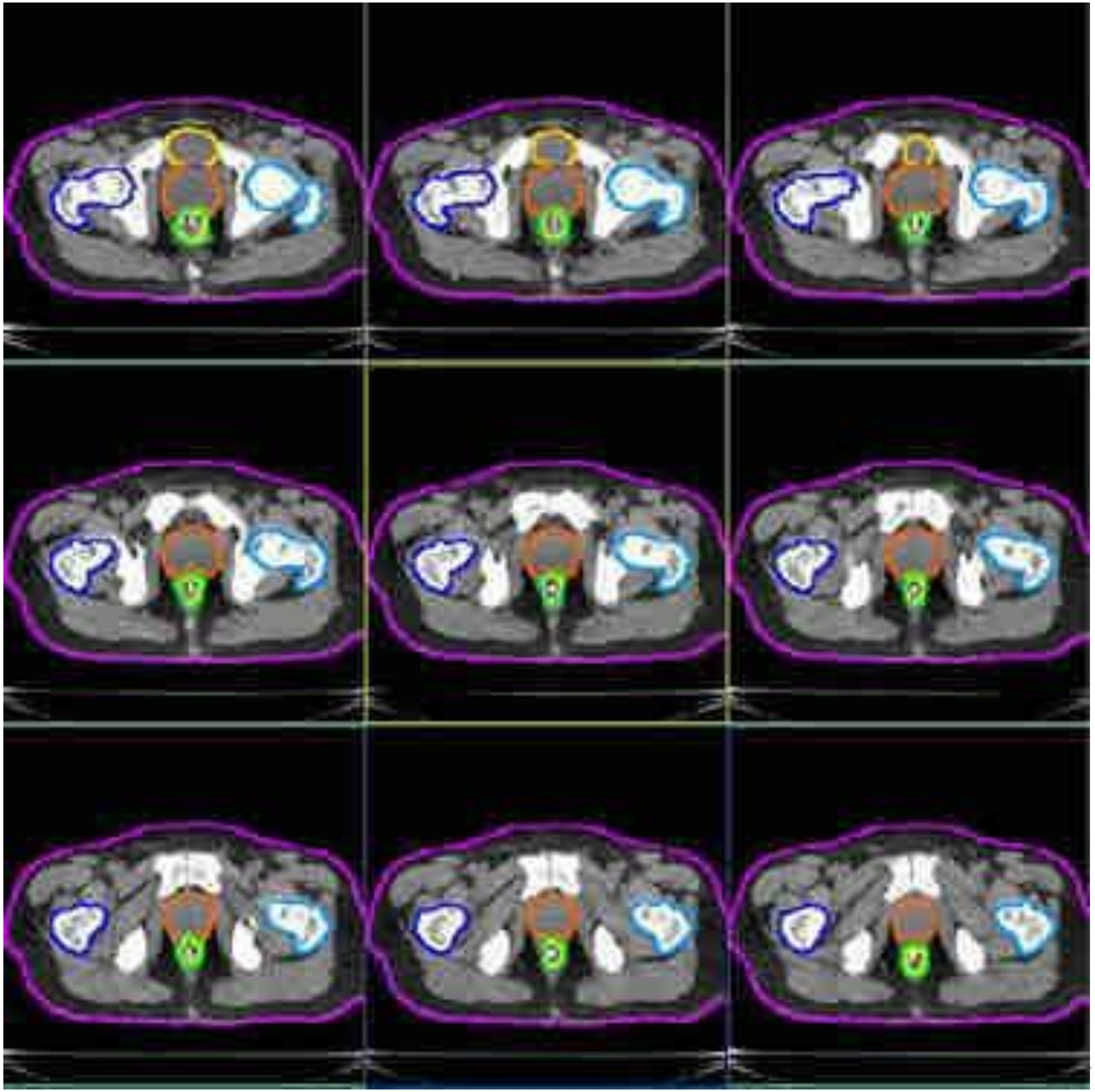
- More radio-resistant tumors require higher doses of RT
  - H&N CA (70 Gy/35 fx)
  - Prostate CA (70-74 Gy)
  - GBM (60 Gy/30 fx)

Process of RT

- 74 y/o pt with CC of prostate cancer
  - T1c, PSA 10, GS 7 (intermediate risk prostate cancer)
- Pt opts for RT
- CT simulation→ CT scan to identify the tumor and surrounding normal structures.
  - Placed in molds/vac fixes that immobilize pt, skin marks placed, so position can be recreated during treatment

Process of RT

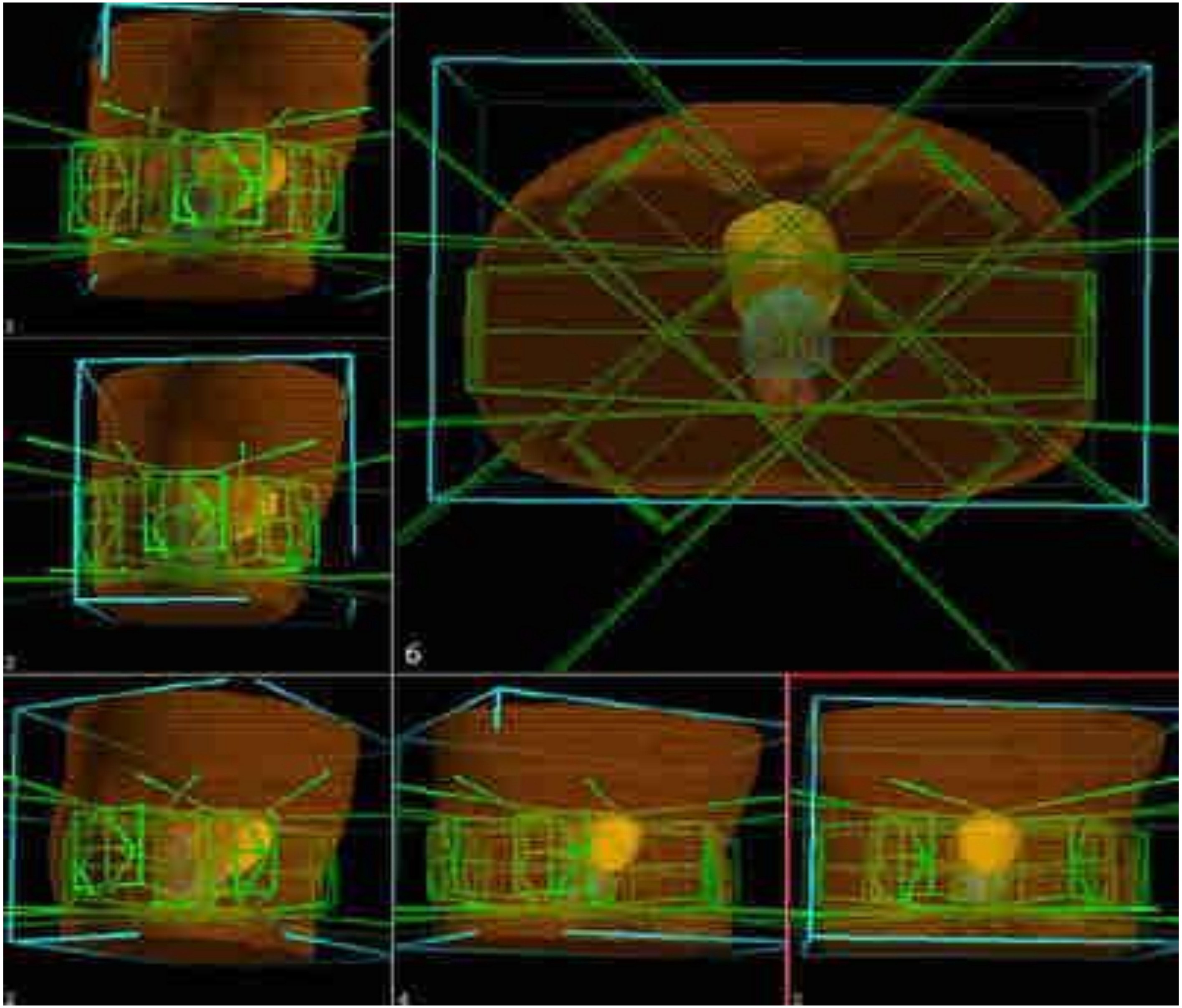
- CT scan loaded onto computers with planning software
- Prostate (gross tumor volume-GTV) and adjacent structures are drawn (contoured) on planning software



http://www.phoenix5.org/Infolink/Michalski/image/fig6_contours.JPG

Process of RT Planning

- Margins are placed around gross tumor volume to encompass microscopic disease spread (clinical tumor volume-CTV)
- Margins are placed around CTV
  - This is the planning tumor volume
- Want highest doses to GTV, CTV and PTV
  - Relatively lower doses to bladder, rectum, small bowel, femoral heads, etc
- Fields placed
- Dose-volume histogram reviewed
  - Graphically summarizes the simulated radiation distribution within a volume of interest of a patient which would result from a proposed radiation treatment plan.



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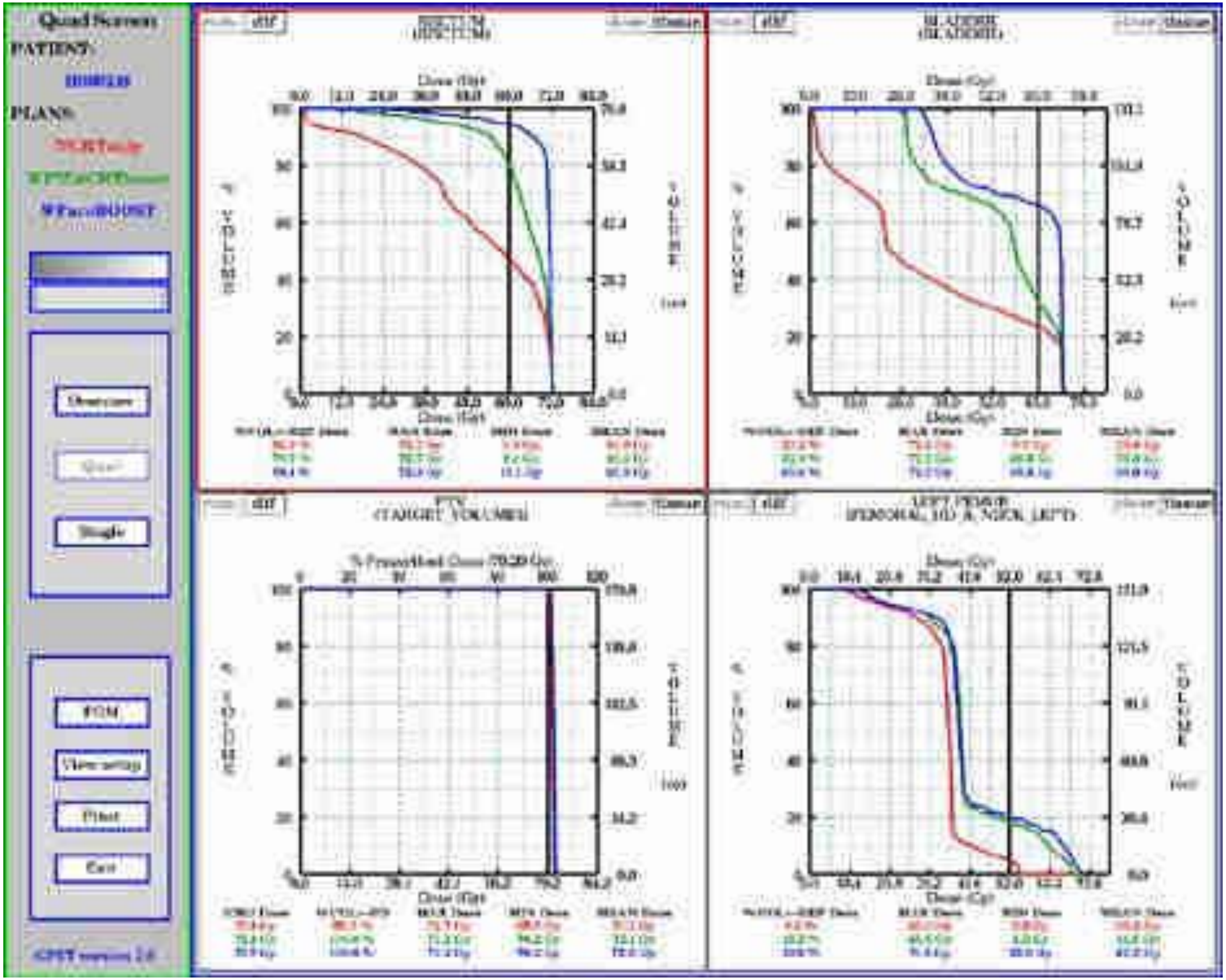

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Process of RT Planning

- Pt returns to RT department to initiate RT approx 7-14 days later
- Undergo a "dry-run"
- After dry-run, pt starts treatment

http://www.insidestory.iop.org/images/linear_accelerator.jpg

Side-Effects[3]

- Acute vs Long term side-effects
  - Side effects usually localized
    - Ex. Acute side effects of prostate cancer
      - Diarrhea
      - Increased frequency of urination
      - Dysuria
      - Skin erythema
    - LT side-effects
      - Decreased sexual functioning
      - Approx 1% risk of injury to bowel or bladder
  - Systemic side effects
    - Fatigue

Intraparenchymal Brain Metastasis

- Clinical Incidence
  - Lung 30-40%
  - Breast 15-25%
  - Melanoma 12-20%
  - Unknown primary 3-8%
  - Colorectal 3-7%
  - Renal 2-6%

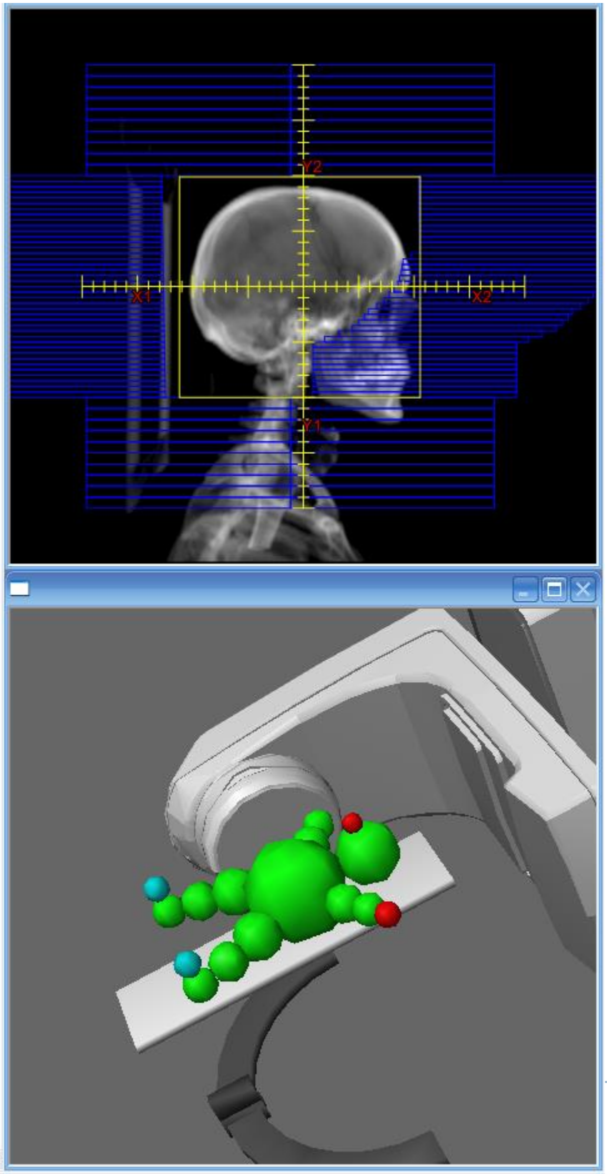
- **Symptoms**
  - Headache 50%
  - Focal weakness 30%
  - Mental disturbance 30%
  - Gait disturbance 20%
  - Seizures 18%
- **Signs**
  - Altered mental status 60%
  - Hemiparesis 60%
  - Hemisensory loss 20%
  - Papilledema 20%
  - Gait ataxia 20%
  - Aphasia 18%

NCCN

Management of Brain Metastases

- **Steroids**
- **Anticonvulsants**
  - Used to manage seizures in patients with brain tumors
  - A significant fraction [40-50%] of such patients do not require AEDs
  - Associated with inherent morbidity
  - Monotherapy preferable
  - May complicate administration of chemotherapy [p450 inducers]
- Surgery
- Radiation therapy
  - Whole brain radiation
  - Stereotactic radiosurgery

Whole brain radiation

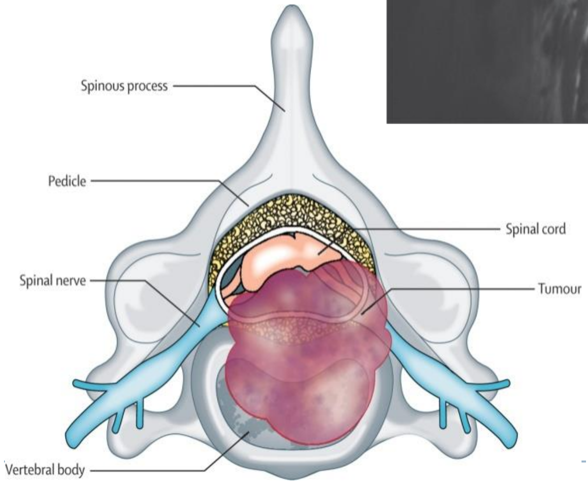


Adverse events:

- Short term:
  - fatigue, hair loss, erythema
- Long term:
  - decreased neurocognitive effects (short term memory, altered executive function)
  - somnolence
  - leukoencephalopathy
  - brain atrophy
  - normal pressure hydrocephalus
  - cataracts
  - RT necrosis

Spinal Cord Compression

- Back pain
- Radicular symptoms
- Neurologic signs and symptoms
  - Often neurologic signs and symptoms are permanent
  - Ambulation and bowel/bladder function at the time of starting therapy correlates highly with ultimate functional outcome
- Plain films
  - 60-80% of patients with epidural disease/spinal cord compression have abnormal plain films
- MRI
  - Order with gad
  - Will show intramedullary lesions
  - Need to obtain a full screening MRI of the spine
- Myelogram/Metrizamide C



Spinal Cord Compression - Treatment

- **Steroids** are recommended for any patient with neurologic deficits suspected or confirmed to have CC. 10 mg IV/po and then 4-6 mg po q6 hrs
- Surgery should be considered for patients with a good prognosis who are medically and surgically operable
  - Radiotherapy after surgery
- RT should be given to nonsurgical patients
- Therapies should be initiated prior to neurological deficits when possible

Loblaw DA et al IJROBP March 2012

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