Role of Radiation Therapy in the Management of Cancer:

Cancer is a common public health issue with one in three Americans developing an invasive non-skin cancer in their lifetime. At least 50% of cancer patients receive radiation therapy at some point during their management.

Tumor Kinetics:

Tumors grow exponentially for a portion of their natural history and have lower limit of detection about 1x10⁹ cells (1 cc³). A lethal volume of cancer is about 1x10¹² cells (1 kg). Most cancers have therefore completed about two-thirds of their natural life span before they are detected.

The Cancer Team:
• Surgical Oncologist
• Medical Oncologist
• Radiation Oncologist
Other Support Services: Radiology, nuclear medicine, pathology, social work, nursing.

Role of Radiation Oncologist:
• Determine if radiation therapy needed
• Recommend type, does and fractionation schedule
• Inform patient re rationale, side effects, and potential late toxicities
• Follow patient during and after treatment

External Beam Radiation Therapy –
Aiming ionizing radiation at a tumor using beams from the outside

Definitions:
Ionizing radiation - energy strong enough to ionize an atom
Gamma Ray – photons emitted from radioactive materials as they decay
X-ray – photons produced by machine
High Energy Photons – produced by a linear accelerator when tungsten target bombarded by high energy electrons.

Kilovoltage (kV) – diagnostic radiology; photoelectric effect creates sharp distinctions between tissue types. Typical Energy range: 25 kV – 150 kV (25,000 – 150,000 V)
**Megavoltage (MV)** – radiation therapy; intentionally ionizing, Compton effect and pair production. Typical Energy range: 4 MV – 20 MV (4,000,000 – 20,000,000 V)

**Conventional EBRT**- simple fields, planning based on bony landmarks

**3D Conformal** – Radiation plan based on CT scan of patient in radiation position

**IMRT** – Intensity modulated radiation therapy, computer-aided planning using multiple (approx. 100) overlapping fields

**Boost** – region of the tumor bed is the area at highest risk of recurrence, so additional radiation is given.

**Determining Dose:**

*Unit of dose* = Gray (Gy)

1 GY = 1 joule/kg, measure of energy deposited in the treated tissue

*Typical dose per day* = 2 Gy

**Case #1 – Breast Mass** –

- Breast conserving therapy with T1 tumor, negative margins, negative nodes.
- Radiation Recommendation is 3D conformal external bema radiation therapy
- Dose= 42.56 Gy + 10 Gy boost
- Fraction size = 2 – 2.66 Gy per day
- Rationale for Radiation in Breast Cancer: If patient opts for breast conserving therapy, radiation therapy should generally be given to reduce the risk of cancer.

**IMRT** – a type of external beam radiation therapy

- Intensity of the radiation beam varies across the radiation field
- Based on CT anatomy
- Inverse treatment planning

**Designing an IMRT Plan**

- Radiation Oncology defines regions to treat and doses to give (gross tumor, prophylactic coverage)
- Also defines regions to avoid (parotid glands, spinal cord, eyes,...)
- Radiation physicist creates plan

Chemo and Radiation Therapy can be given at the same time. The combination has been proven to improve cancer control rates for many tumors, including lung, pancreas, rectum, esophagus, anal, stomach, brain. The downside is increased toxicity

**Case #2 - Sore Throat** –

- 55 yo male, 40 pack/year smoker, complains of sore throat
- Ulcer seen in the right tonsil and hard 3 cm right neck node present
- Referral to ENT for tonsil bx and FNA of the neck node.
- Pathology shows poorly differentiated squamous cell carcinoma in both.
- Treatment Options:
  - Surgery followed by radiation
  - Radiation followed by surgery
  - Chemo-radiation
- Patient decides on chemo-radiation – a common curative approach for advanced head and neck cancers.
- Radiation Recommendation IMRT to a total dose of 70 Gy to regions of gross disease; concurrent q3 weekly cisplatin chemotherapy, post-treatment imaging at 8 weeks to assess response.

BRACHYTHERAPY – placement of radioactive materials into or immediately adjacent to the cancer.

- Requires an invasive procedure
- May be done alone or in combination with external beam therapy

**HDR vs LDR**

Low Dose Rate (LDR)
- Source may be placed temporarily or permanently
- **Radiation delivered over days to weeks**
- Typical isotope for gyne cases = Cs-137
- Typical isotopes for PPI cases = I-125 and Pd-103

High Dose Rate (HDR)
- Radiation source is temporarily placed in patient and then removed
- **Source is very “hot” so high doses of radiation given in minutes**
- Typical isotope=Ir-192

Permanent Prostate Implant
- Radioactive seeds inserted into the prostate and remain there forever (LDR)
- Seeds are loaded into needles
- Needles directed thru the perineum and into the prostate under ultrasound guidance

Case #3 – Rising PSA –

- 64 yo male for routine H&P, including cancer screening tests including PSA
- PSA = 4.5, 2 years ago it was 1.3
- Digital rectal exam WNL
- Refer to urologist for prostate biopsy – diagnoses prostate cancer
- Treatment options include radical prostatectomy, radiation therapy, watchful waiting
- Radiation Options
  - External beam radiation therapy – Total dose around 78 Gy; approx. 40 treatments
  - Low dose rate brachytherapy (permanent)
  - High dose rate brachytherapy (temporary)

- **Prostate Cancer is Commonly Treated with Brachytherapy Alone**
- **In terms of survival, there is no obvious benefit to surgery over radiation.**

Other Types of brachytherapy include
- Prostate HDR
- Head and Neck HDR
- Gynecologic LDR
- Gynecologic HDR
- Intraoperative brachytherapy
- Coronary brachytherapy
RADIOSURGERY – short course, high dose, very focused external beam radiation treatment

Ways to perform radiosurgery:
- Gamma Knife
- Linear accelerator based
- Cyberknife

Gamma Knife Radiosurgery
- Rigid patient immobilization, within 1 mm
- 201 cross-firing tiny radiation beams give extremely high doses to small points in the brain
- Accurate MRI based radiation treatment planning

Cyberknife Radiosurgery
- Miniature linear accelerator mounted on robot arm
- Can treat tumors located anywhere in the body
- Built-in ability to track moving tumor target

Case #4 – Breast Cancer patients returns 4 years after initial diagnosis with headache and nausea. MRI scan shows new brain metastases –
- Treatment Options
  - Whole brain radiation therapy
  - Radiosurgery
  - Brain RT and radiosurgery boost

INTRAOPERATIVE RADIOTHERAPY (IORT) – short course, high dose, very focused external beam radiation treatment

FACTS:
- Whole breast irradiation reduced local recurrence rate from 30-40% to < 10%
- Tumors < 1cm without RT 16.5% Local recurrences
- 90% local recurrences are in the index quadrant independent of applied radiotherapy

TARGIT Technique - Accurately delivers radiotherapy from within the breast in about 25 minutes.
RADIATION SAFETY

- ALARA = As Low As Reasonably Achievable!
- Time – minimize the time you are exposed
- Distance – $1/R^2$, 2 times the distance is 4 times less dose
- Shielding

TYPICAL RADIATION DOSES

- Conversions: $10 \text{ mSv} = 1 \text{ rad} = 1 \text{ rem} = 1 \text{ cGy}$
- Natural background, radon = $2 \text{ mSv/year}$
- Natural background, other (cosmic, etc) = $1 \text{ mSv/year}$
- Commercial flight, USA to Europe = $0.05 \text{ mSv}$
- CXR = $0.02 - 0.05 \text{ mSv}$
- CT scan = $0.34 - 7.8 \text{ mSv}$ (depending on part of body scanned)
- PET scan = $11 \text{ mSv}$
- Fluoroscopy = 3-20 R/minute surface dose
- Public exposure limit, continuous/frequent = $1 \text{ mSv/year}$
- Public exposure limit, infrequent = $5 \text{ mSv/year}$

LESSON FOR DEFINING IF A PATIENT HAS A RADIATION TOXICITY

- In order to diagnosis radiation toxicity it is critical to know the exact areas irradiated and the dose.

SUMMARY

- The radiation oncologist is an important member of the cancer team
Common radiation treatments include:
- External bema radiation: Conventional, 3D conformal, IMRT
- Brachytherapy: HDR, LDR
- Radiosurgery

Radiation can be used:
- Before surgery
- After surgery
- Alone
- In combination with chemotherapy

Goals of radiation:
- Cure Cancer
- Palliation in incurable patients