An Overview of Radiation Therapy for Health Care Professionals

ASTRO

American Society for Radiation Oncology

Introduction

- Radiation has been an effective tool for treating cancer for more than 100 years
- More than 60 percent of patients diagnosed with cancer will receive radiation therapy as part of their treatment
- Radiation oncologists are cancer specialists who manage the care of cancer patients with radiation for either cure or palliation

Patient being treated with modern radiation therapy equipment.

Overview

- What is the physical and biological basis for radiation
- What are the clinical applications of radiation in the management of cancer
- What is the process for treatment
  - Simulation
  - Treatment planning
  - Delivery of radiation
- What types of radiation are available
- Summary

What Is the Biologic Basis for Radiation Therapy?

- Radiation therapy works by damaging the DNA of cells and destroys their ability to reproduce
- Both normal and cancer cells can be affected by radiation, but cancer cells have generally impaired ability to repair this damage, leading to cell death
- All tissues have a tolerance level, or maximum dose, beyond which irreparable damage may occur

Fractionation: A Basic Radiobiologic Principle

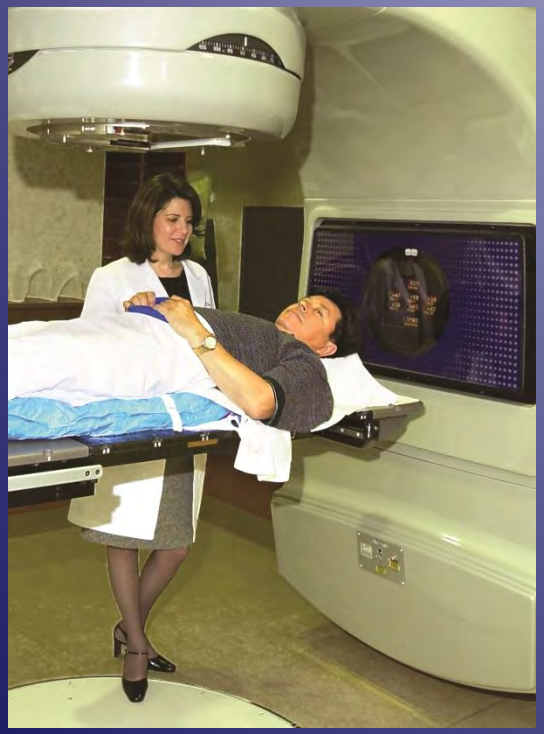
- Fractionation, or dividing the total dose into small daily fractions over several weeks, takes advantage of differential repair abilities of normal and malignant tissues

- Fractionation spares normal tissue through **repair** and **repopulation** while increasing damage to tumor cells through **redistribution** and **reoxygenation**

The Four R's of Radiobiology

- Four major factors are believed to affect tissue's response to fractionated radiation:
  - **Repair** of sublethal damage to cells between fractions caused by radiation
  - **Repopulation** or regrowth of cells between fractions
  - **Redistribution** of cells into radiosensitive phases of cell cycle
  - **Reoxygenation** of hypoxic cells to make them more sensitive to radiation

Clinical Uses for Radiation Therapy



External beam radiation treatments are usually scheduled five days a week and continue for one to ten weeks

- Therapeutic radiation serves two major functions
  - To cure cancer
    - Destroy tumors that have not spread
    - Kill residual microscopic disease left after surgery or chemotherapy
  - To reduce or palliate symptoms
    - Shrink tumors affecting quality of life, e.g., a lung tumor causing shortness of breath
    - Alleviate pain or neurologic symptoms by reducing the size of a tumor

Radiation Therapy in Multidisciplinary Care

- Radiation therapy plays a major role in the management of many common cancers either alone or as an adjuvant therapy with surgery and chemotherapy
  - Sites commonly treated include breast, prostate, lung, colorectal, pancreas, esophagus, head and neck, brain, skin, gynecologic, lymphomas, bladder cancers and sarcomas
- Radiation is also frequently used to treat brain and bone metastases as well as cord compression

Radiation Therapy Basics

- The delivery of external beam radiation treatments is painless and usually scheduled five days a week for one to ten weeks
- The effects of radiation therapy are cumulative with most significant side effects occurring near the end of the treatment course.
  - Side effects usually resolve over the course of a few weeks
  - There is a slight risk that radiation may cause a secondary cancer many years after treatment, but the risk is outweighed by the potential for curative treatment with radiation therapy

Example of erythroderma after several weeks of radiotherapy with moist desquamation

Source: sarahscancerjourney.blogspot.com

Common Radiation Side Effects

Unlike the systemic side effects from chemotherapy, radiation therapy usually only impacts the area that received radiation

Side effects during the treatment vary depending on site of the treatment and affect the tissues in radiation field:

- Breast – swelling, skin redness
- Abdomen – nausea, vomiting, diarrhea
- Chest – cough, shortness of breath, esophogeal irritation
- Head and neck – taste alterations, dry mouth, mucositis, skin redness
- Brain – hair loss, scalp redness
- Pelvis – diarrhea, cramping, urinary frequency, vaginal irritation
- Prostate – impotence, urinary symptoms, diarrhea
- Fatigue is often seen when large areas are irradiated

Modern radiation therapy techniques have decreased these side effects significantly

Palliative Radiation Therapy

- Commonly used to relieve pain from bone cancers
  - ~ 50 percent of patients receive total relief from their pain
  - 80 to 90 percent of patients will derive some relief
- Other palliative uses:
  - Spinal cord compression
  - Vascular compression, e.g., superior vena cava syndrome
  - Bronchial obstruction
  - Bleeding from gastrointestinal or gynecologic tumors
  - Esophageal obstruction

Radiation is effective therapy for relief of bone pain from cancer

The Radiation Oncology Team

- Radiation Oncologist
  - The doctor who prescribes and oversees the radiation therapy treatments
- Medical Physicist
  - Ensures that treatment plans are properly tailored for each patient, and is responsible for the calibration and accuracy of treatment equipment
- Dosimetrist
  - Works with the radiation oncologist and medical physicist to calculate the proper dose of radiation given to the tumor
- Radiation Therapist
  - Administers the daily radiation under the doctor's prescription and supervision
- Radiation Oncology Nurse
  - Interacts with the patient and family at the time of consultation, throughout the treatment process and during follow-up care

The Treatment Process

- Referral
- Consultation
- Simulation
- Treatment Planning
- Quality Assurance

Referral

- Tissue diagnosis has been established
- Referring physician reviews potential treatment options with patient
- Treatment options may include radiation therapy, surgery, chemotherapy or a combination

It is important for a referring physician to discuss all possible treatment options available to the patient

Consultation

- Radiation oncologist determines whether radiation therapy is appropriate
- A treatment plan is developed
- Care is coordinated with other members of patient's oncology team

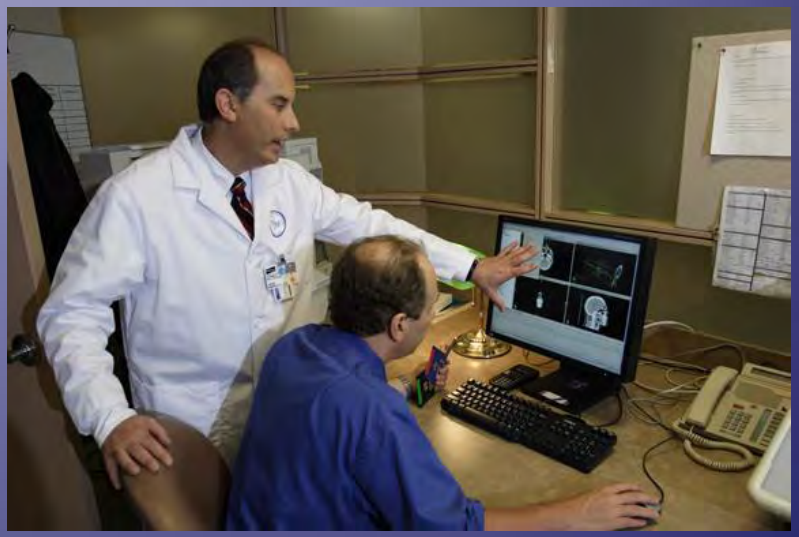
The radiation oncologist will discuss with the patient which type of radiation therapy treatment is best for their type of cancer

Simulation

- Patient is set up in treatment position on a dedicated CT scanner
  - Immobilization devices may be created to assure patient comfort and daily reproducibility
  - Reference marks or "tattoos" may be placed on patient
- CT simulation images are often fused with PET or MRI scans for treatment planning

Treatment Planning

- Physician outlines the target and organs at risk
  - Sophisticated software is used to carefully derive an appropriate treatment plan
    - Computerized algorithms enable the treatment plan to spare as much healthy tissue as possible
  - Medical physicist checks the chart and dose calculations
  - Radiation oncologist reviews and approves final plan



Radiation oncologists work with medical physicists and dosimetrists to create the optimal treatment plan for each individualized patient

Safety and Quality Assurance

- Each radiation therapy treatment plan goes through many safety checks
  - The medical physicist checks the calibration of the linear accelerator on a regular basis to assure the correct dose is being delivered
  - The radiation oncologist, along with the dosimetrist and medical physicist go through a rigorous multi-step QA process to be sure the plan can be safely delivered
  - QA checks are done by the radiation therapist daily to ensure that each patient is receiving the treatment that was prescribed for them

Delivery of Radiation Therapy

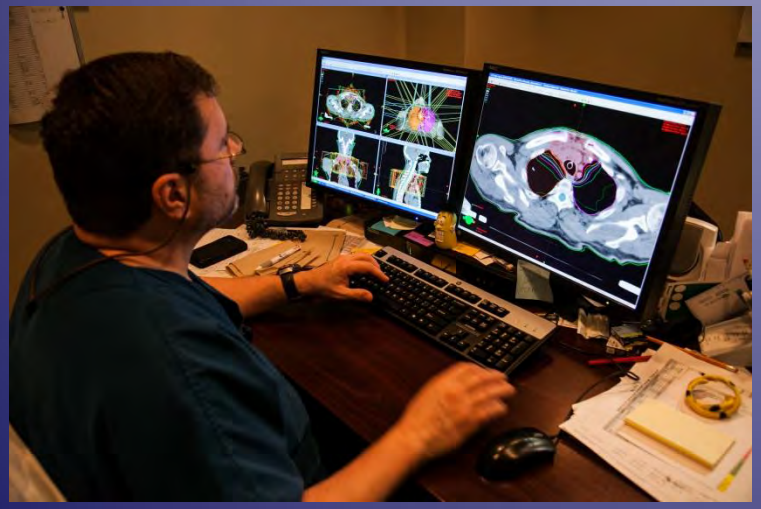
The type of treatment used will depend on the location, size and type of cancer.

- *External beam* radiation therapy typically delivers radiation using a linear accelerator
- Internal radiation therapy, called *brachytherapy*, involves placing radioactive sources into or near the tumor
- The modern unit of radiation is the *Gray (Gy)*, traditionally called the *rad*
  - 1Gy = 100 centigray (cGy)
  - 1cGy = 1 rad

Types of External Beam Radiation Therapy

- Two-dimensional radiation therapy
- Three-dimensional conformal radiation therapy (3-D CRT)
- Intensity modulated radiation therapy (IMRT)
- Image Guided Radiation Therapy (IGRT)
- Intraoperative Radiation Therapy (IORT)
- Stereotactic Radiotherapy (SRS/SBRT)
- Particle Beam Therapy

Three-Dimensional Conformal Radiation Therapy (3-D CRT)



- Uses CT, PET or MRI scans to create a 3-D picture of the tumor and surrounding anatomy
  - Improved precision, decreased normal tissue damage

Intensity Modulated Radiation Therapy (IMRT)

- A highly sophisticated form of 3-D CRT allowing radiation to be shaped more exactly to fit the tumor
  - Radiation is broken into many "beamlets," the intensity of each can be adjusted individually
- IMRT allows higher doses of radition to be delivered to the tumor while sparing more healthy surrounding tissue

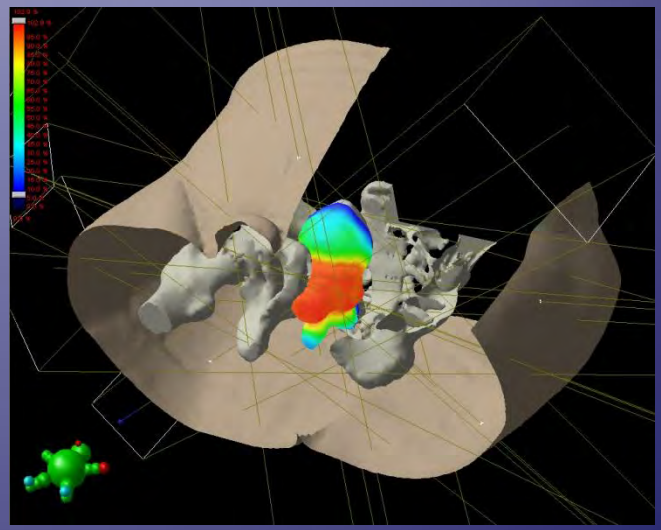
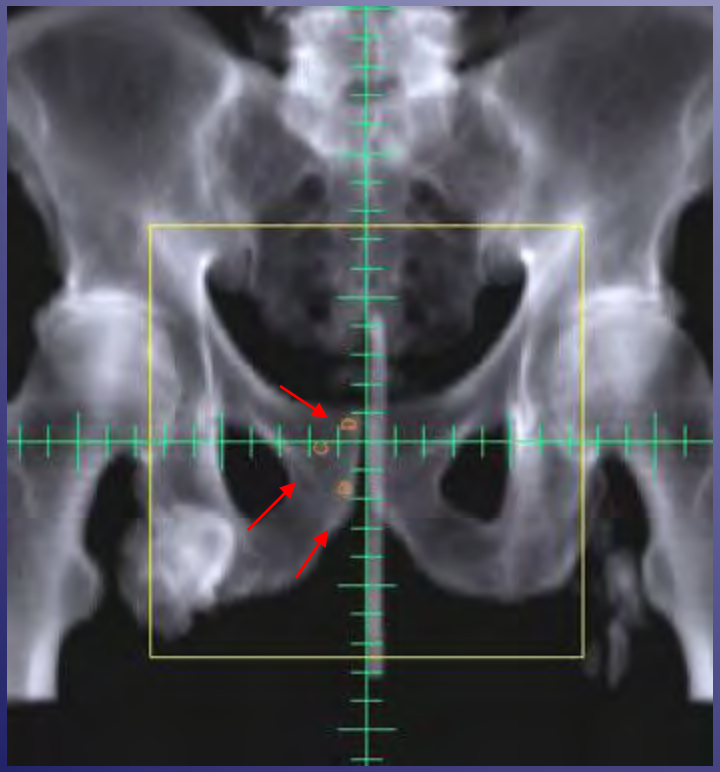


Image Guidance

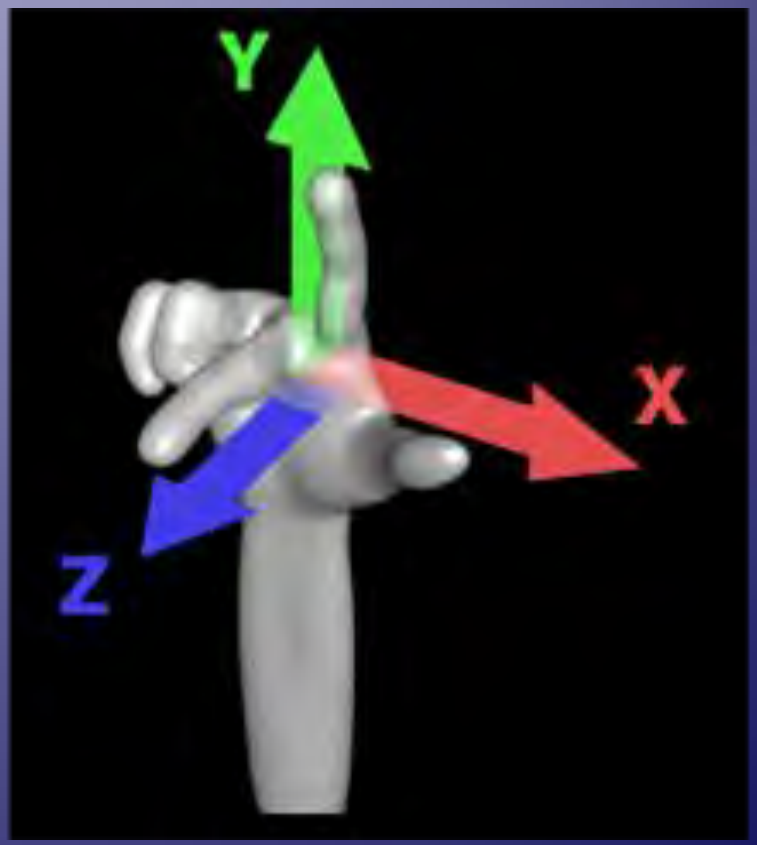


Fiducial markers in prostate visualized and aligned

- For patients treated with 3-D or IMRT
- Physicians use frequent imaging of the tumor, bony anatomy or implanted fiducial markers for daily set-up accuracy
  - Imaging performed using CT scans, high quality X-rays, MRI or ultrasound
  - Motion of tumors can be tracked to maximize tumor coverage and minimize dose to normal tissues

Stereotactic Radiosurgery (SRS)

- SRS is a specialized type of external beam radiation that uses focused radiation beams targeting a well-defined tumor
  - SRS relies on detailed imaging, 3-D treatment planning and complex immobilization for precise treatment set-up to deliver the dose with extreme accuracy
  - Used on the brain or spine
  - Typically delivered in a single treatment or fraction



Stereotactic Body Radiotherapy (SBRT)

- SBRT refers to stereotactic radiation treatments in 1-5 fractions on specialized linear accelerators
  - Uses sophisticated imaging, treatment planning and immobilization techniques
    - Respiratory gating may be necessary for motions management, e.g., lung tumors
  - SBRT is used for a number of sites: spine, lung, liver, brain, adrenals, pancreas
  - Data maturing for sites such as prostate

Proton Beam Therapy

- Protons are charged particles that deposit most of their energy at a given depth, minimizing risk to tissues beyond that point
- Allows for highly specific targeting of tumors located near critical structures
- Increasingly available in the U.S.
- Most commonly used in treatment of pediatric, CNS and intraocular malignancies
  - Data maturing for use in other tumor sites

Proton Gantry

Source: Mevion

Types of Internal Radiation Therapy

- Intracavitary implants
  - Radioactive sources are placed in a cavity near the tumor (breast, cervix, uterine)
- Interstitial implants
  - Sources placed directly into the tissue (prostate, vagina)
- Intra-operative implants
  - Surface applicator is in direct contact with the surgical tumor bed

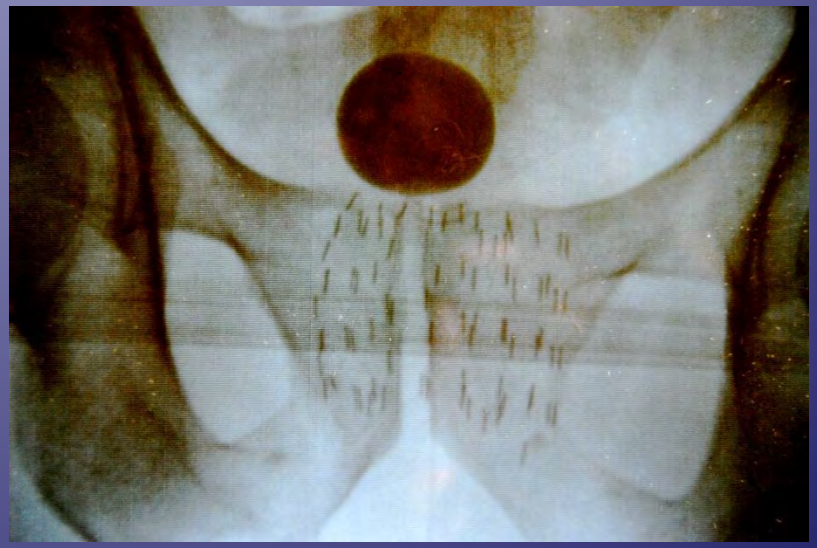
Brachytherapy

- Radioactive sources are implanted into the tumor or surrounding tissue
  - ^{125}I, ^{103}Pd, ^{192}Ir, ^{137}Cs
- Purpose is to deliver high doses of radiation to the desired target while minimizing the dose to surrounding normal tissues

Radioactive seeds for a permanent prostate implant, an example of low-dose-rate brachytherapy.

Brachytherapy Dose Rate

- Low-Dose-Rate (LDR)
  - Radiation delivered over days and months
    - Prostate, breast, head and neck, and gynecologic cancers may be treated with LDR brachytherapy
- High-Dose-Rate (HDR)
  - High energy source delivers the dose in a matter of minutes rather than days
    - Gynecologic, breast, head and neck, lung, skin and some prostate implants may use HDR brachytherapy



LDR prostate implant

Permanent vs. Temporary Implants

- Permanent implants release small amounts of radiation over a period of several months
  - Examples include low-dose-rate prostate implants (“seeds”)
  - Patients receiving permanent implants may be minimally radioactive and should avoid close contact with children or pregnant women
- Temporary implants are left in the body for several hours to several days
  - Patient may require hospitalization during the implant depending on the treatment site
  - Examples include low-dose-rate GYN implants and high-dose-rate prostate or breast implants

Intraoperative Radiation Therapy (IORT)

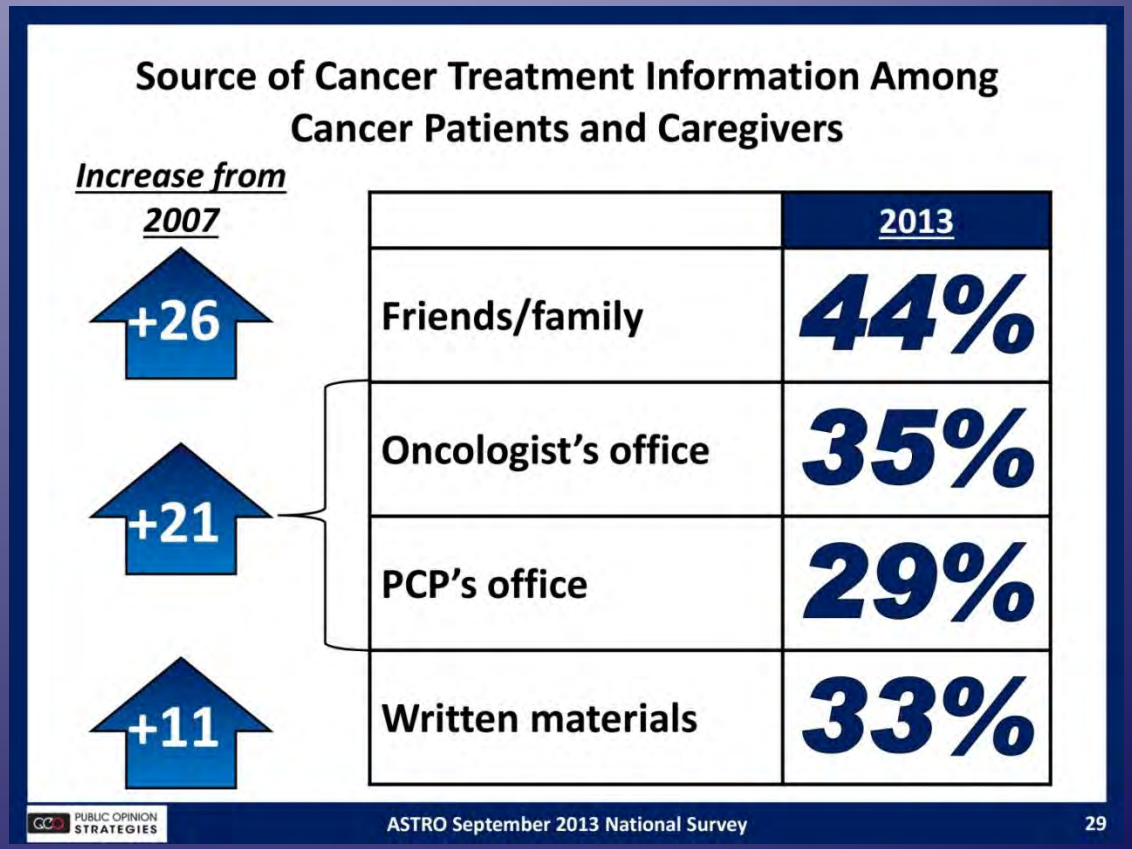
- IORT delivers a concentrated dose of radiation therapy to a tumor bed during surgery
  - Advantages
    - Decrease volume of tissue in boost field
    - Ability to exclude part or all of dose-limiting normal structures
    - Increase the effective dose
  - Multiple sites
    - Pancreas, stomach, lung, esophagus, colorectal, sarcomas, pediatric tumors, bladder, kidney, gyn
    - Several recent trials have shown efficacy for breast cancer

Systemic Radiation Therapy

- Radiation can also be delivered by an injection.
  - Metastron (^{89}Strontium), Quadramet (^{153}Samarium) and Xofigo (^{223}Radium) are radioactive isotopes absorbed primarily by cancer cells
    - Used for treating bone metastases
  - Radioactive isotopes may be attached to an antibody targeted at tumor cells
    - Zevalin, Bexxar for Lymphomas
  - Radioactive "beads" may be used to treat primary or metastatic liver cancer
    - Y^{90}-Microspheres

Public Awareness of Radiation Therapy

- Patients report going to friends and family and their referring physician to get cancer treatment information



Summary

- Radiation therapy is a well established modality for the treatment of numerous malignancies
- Radiation oncologists are specialists trained to treat cancer with a variety of forms of radiation
- Treatment delivery is safe, quick and painless

For More Information…

- The American Society for Radiation Oncology (ASTRO) can provide information on radiation therapy
- Visit www.rtanswers.org to view information on how radiation therapy works to treat various cancers