Radiation Therapy

- Therapeutic use of electromagnetic energy from a machine or radioactive source or particles to treat disease, primarily malignancies
  - X-rays: generated from electrical machine such as a linear accelerator
  - Gamma rays: generated from a radioactive source
  - Unit of dose measurement: rad=Gy (1 Gy=100rad)
External Beam Radiation

- External beam radiation is a source of radiation outside of the body delivered by a linear accelerator.

- The radiation beams are tailored to include the tumor, a margin, and spare healthy tissue.
Linear Accelerator
Internal Radiation

- Source of radiation placed inside the body
  - Brachytherapy
    - Sealed sources
  - Radiopharmaceutical therapy
    - Unsealed sources
Fractionation

- **Standard**
  - Single fraction 5 days a week

- **Hyperfractionation**
  - Smaller doses given more than once a day

- **Accelerated fractionation**
  - Shorter overall treatment time
  - Standard doses with increased number of fractions a day
    - Hypofractionation
  - Shorter treatment time using greater than standard 1.8-2Gy fraction
Pulsed Low Dose Rate

- Potential to reduce late normal tissue toxicity while providing tumor control
- Used for re-irradiation
- PLDR treatments deliver 20cGy pulses separated by 3-minute intervals
  - At lower dose-rated cell proliferation continues during the treatment
Simulation

- Radiation planning
- Immobilization
- X-ray machines with the ability to duplicate the radiation machines
  - Inclusion of body contour, outline and depth of internal structures, location and size of tumor
- CT and/or MRI scan used to create detailed 3D or 4D representations of the tumor and surrounding tissues
- Sliced scan images
  - Planning team: physician, physicists, dosimetrists
Simulation

- CT, MRI, PET fusion
- Clinical spectroscopy
  - Nuclear medicine tomographic imaging technique
  - Provides clinical measurement of chemicals within organs eg. Brain and prostate
- Respiratory gaiting
  - Tracking motion
  - Respiratory gaiting system turns off the radiation beam when a tumor moves out of the treatment area
4D CT

- Organ motion can cause severe distortions in breathing CT scan

- Many 3D sets are obtained, each corresponding to a particular breathing phase

- Together they constitute a 4-D CT set that covers the entire breathing cycle
External Beam Radiation
Conventional

- Two dimensional

- Uses x ray images of treatment area relative to bony landmarks

- Rectangular shaped fields

- Use of blocks and wedges
Conformal Radiation

Three-dimensional (3D) is a technique where the beams of radiation are shaped to match the tumor

- Geometric field shaping
- Each beam is given a shape that attempts to match the outline of the tumor
- Allows higher dose to tumor with less side effects
Intensity Modulated Radiotherapy
IMRT

- Most advanced form of 3D conformal radiotherapy
- Multiple fields and angles
- Intensity is varied within the shaped field; certain regions of the beam deliver a high dose while other regions deliver a low dose
- Multiple beams are oriented around the patient
- Beams are created by use of multileaf collimator
IMRT

- Less damage to normal tissue

- Ability to deliver higher dose to the tumor

- The beam intensity varies across the treatment field

- The small beams are created by use of a multileaf collimator
Image Guided Radiation Therapy (IGRT)

- Use of x-rays and scans before and during radiation treatment
- Allows adjustments with changes in tumor position, size, shape between fractions and within a fraction

Advantages

- May increase tumor control
- Decrease side effects
- Allows shorter causes of radiation
IGRT Methods

Use of treatment beam

- Position of the skeleton relative to the treatment field
  - Compare to reference images made during simulation
  - Set-up with assistance of lasers and tattoos and bony landmarks

- CT on rails
  - The gantry encircles the patient, when the image acquisition is complete it retracts

- Tomotherapy
  - Built in image guidance using CT scanner
  - The patient advances slowly through the ring gantry
CT on RAILS
IGRT Methods

Ultrasound

- Used for daily setup
- For pelvic and upper abdominal tumors
  - Combines an ultrasound probe and a 3D positioning tool to pinpoint organs at the time of each treatment session
IGRT Methods

Implant radiographic markers

- Gold seeds implanted
- Identified by x ray before every treatment
- The patient is positioned based on the position of the gold seeds
IGRT Methods

Calypso

- Radiofrequency transponders called beacons are placed
- Communication with Calypso 4D Localization System using radiofrequency waves
- Monitors movement in real time during the treatment
IGRT Methods

Cone Beam

- CT based image guidance systems integrated with the linear accelerator
- Allows for monitoring through the treatment process
- CT acquires many projections over the treatment volume
- 2D projections are reconstructed into a 3D volume
4D CT

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- Many 3D sets are obtained, each corresponding to a particular breathing phase
- Together they constitute a 4-D CT set that covers the entire breathing cycle
Stereotactic radiosurgery
SRS

- A non-surgical radiation therapy used to treat functional abnormalities and small tumors of the brain
- Delivery of precisely-targeted radiation in fewer high-dose treatments than traditional therapy
- Accuracy within 1-2 millimeters
Stereotactic Radiosurgery and Radiotherapy

Used to treat many types of brain lesions

- Benign and malignant
- Primary and metastatic
- Single and multiple
- Residual tumor following surgery
- Intracranial, orbital, and base-of-skull tumors
- Arteriovenous malformations (AVMs)
- Other neurological conditions like trigeminal neuralgia
Stereotactic Body Radiotherapy
SBRT

Alternative to surgery, especially for patients who are unable to undergo surgery and for tumors that are:

- Hard to reach
- Located close to vital organs, anatomic regions
- Subject to movement within the body
SBRT

Uses
- Lung
- Liver
- Abdomen
- Spine
- Prostate
- Head and neck
SRT and SBRT

Simulation
Immobilization
- Head frame
- Aquaplast “mask”
- Body immobilization
CT, MRI, PET simulation
May require fiducial markers
Equipment

- Gamma knife: uses 192 or 201 beams of highly focused gamma rays all aiming at the target region
- Linear accelerator
- CyberKnife
  - Robotic radiosurgery system mounted on a robotic arm on a linear accelerator
  - Delivers large doses of radiation to very small areas by aiming multiple small x-ray beams from any direction
  - Continuous image guidance with many different angles
Proton Therapy

- Proton beams consist of energized particles that are accelerated using megavoltage energy
- Protons deposit a small portion of energy in the skin and superficial tissue
- Concentrated energy delivered to the target
- Protons stop at the distal margin of the target
- Have minimal side scatter
Brachytherapy

- A form of radiotherapy where a sealed radiation source is placed inside or next to the area requiring treatment
- Can be used alone or in combination with other therapies such as surgery, external beam radiotherapy, and chemotherapy
- Precise placement of if short-range radiation sources (radioisotopes) enclosed in a protective capsule or wire
Dose Rate

- Low-dose rate (LDR) brachytherapy
  - Radiation sources emit radiation at a rate of up to 2 Gy per hour
  - Used for cancers or the oral cavity, oropharynx, sarcomas, and prostate cancer

- High-dose rate (HDR) brachytherapy
  - Rate of dose delivery exceeds 12 Gy per hr.
  - Used for tumors of the cervix, esophagus, lungs, breast, and prostate
Procedure

- Treatment planning: tumor imaging
- Placement of brachytherapy source applicators
- A 3D visualization and the applicators to define the planned delivery of the radioactive source
- Treatment delivery
Source Placement

- Interstitial brachytherapy
  - The sources are placed directly in the target tissue such as prostate or breast

- Contact brachytherapy
  - Placement of the radiation source in a space next to the target
    - Intracavitary: cervix, uterus, vagina
    - Intraluminal: trachea, esophagus
    - Surface: skin
    - Blood vessels: coronary in-stent restenosis
HDR Prostate Brachytherapy
HDR Tandem & Ring
HDR Endobronchial Brachytherapy
Side Effects

- Acute
  - Localized bruising, swelling, bleeding, discharge or discomfort within the implanted region
  - Fatigue for a short period
  - For cervical or prostate treatment urinary symptoms and/or bowel symptoms
  - For skin cancer desquamation
  - For oral cancer ulceration
    - restenosis
Side Effects

- Long term
  - Urinary or digestive problems may persist
  - Brachytherapy for prostate cancer may cause erectile dysfunction
  - Brachytherapy for skin cancer may cause scar tissue
  - For breast cancer fat necrosis may occur
Radiopharmaceuticals

- Drugs that contain radioactive materials (radioisotopes).
- Given intravenously, by mouth, or placed in a body cavity.
- Mostly in the form of alpha and beta particles that target the specific area.
Radiopharmaceuticals

- Treatment of bone pain
  - Strontium-89 (Metastron), samarium 153 (Quadramet), radium 223 (Xofigo)
- Treatment of thyroid cancer
- Iodine 131
- Radio-labeled antibodies (radioimmunotherapy)
  - Monoclonal antibodies paired with radioactive atoms
HIFU
High Intensity Focused Ultrasound

- Therapeutic ultrasound that induces hyperthermia
- MRI provides image guidance
- High intensity focused ultrasound beams heat and destroy targeted tissue non-invasively
- The target receives multiple pulses of focused ultrasound
SIR-Spheres
y-90 Resin Microspheres

- Resin beads that contain the radioactive isotope Yttrium-90
- 1/3 size of a human hair
- Similar density to blood cells
- Travel with the bloodstream to liver tumors
- Become lodged in the blood supply of the tumor to kill cancer cells
- Emit radiation for about 2 weeks
Work-up session

- Liver angiogram, lung and CT scan
  - To work out a road map
  - To block-off potential escape pathways to gut vessels with tiny metallic coils
  - To work-out correct SIR-Sphere dose
  - Injection of a dummy radioactive tracer to work out shunting to the lungs
The Treatment

- Catheter through groin artery, advanced into the hepatic artery which supplies the liver tumors with blood
- Millions of microspheres are delivered to the tumor site
- Delivers up to 40 times more radiation to the liver tumors than using normal external beam radiation
- The treatment takes about 60-90 minutes
Side Effects

- Abdominal pain or tightness in the abdomen
- Nausea
- Loss of appetite
- Mid fever
- Fatigue
- Rare: if spheres reach the gallbladder, stomach, intestine, pancreas can cause inflammation or ulceration
Precautions

- First 24 hours
  - Hand washing
  - Cleaning of spills of body fluids
  - No pregnancy within two months of receiving treatment
Radiodynamic Therapy

- Racetrack microtron delivers radiation at very high energies
- Treatment consists of high-energy (45MV) photon beams in conjunction with a photosensitizing drug which is the activating agent
  - The oxygen component of the photosensitizer can be activated (become radioactive) at 35-45MV
  - The tumor cells have a 10-20 times higher uptake of the photosensitizer, are irradiated and damaged
The Procedure

- Simulation to define the tumor
- Injection of photosensitizer (Photofrin)
- Radiation 4-6 hours later to allow the agent to leave the normal cells
- The microtron unit allows radiation to penetrate the skin, tissues, and bones to activate photosensitizers in areas deep within the body
Side Effects

Light sensitivity
- Can continue for several weeks, can affect eyes and skin
- Patients should remain away from harsh light, such as sunlight
  - Dark sunglasses
  - Gloves
  - Wide brimmed hat
  - Keep curtains closed for 30 days
Patient Population for Treatment

Palliative patients with cancers of
- The brain
- Head and neck
- Breast
- Lung
- Colon
- Gyn
- Prostate
Side Effects of Radiation

- Fatigue
- Skin reactions
- Pain
- Gastrointestinal
  - Anorexia
  - Nausea
  - Vomiting
  - Diarrhea
  - Proctitis

- Head and neck
  - Dysphagia and odynophagia
  - Mucositis
  - Xerostomia
  - Taste changes/loss
  - Laryngitis

- Genitourinary
  - Irritable bladder symptoms
  - Hemorrhagic cystitis
  - Obstructive symptoms
Patient Education

- Treatment side effects
  - Confined to the treatment area
  - Acute: develops about 2-3 weeks after the start of radiation and lasts about one month or longer after the completion of treatment
  - Late: occurs months to years after radiation is completed and may be permanent
Patient Education

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Thank you!