UNDERSTANDING RADIATION ONCOLOGY

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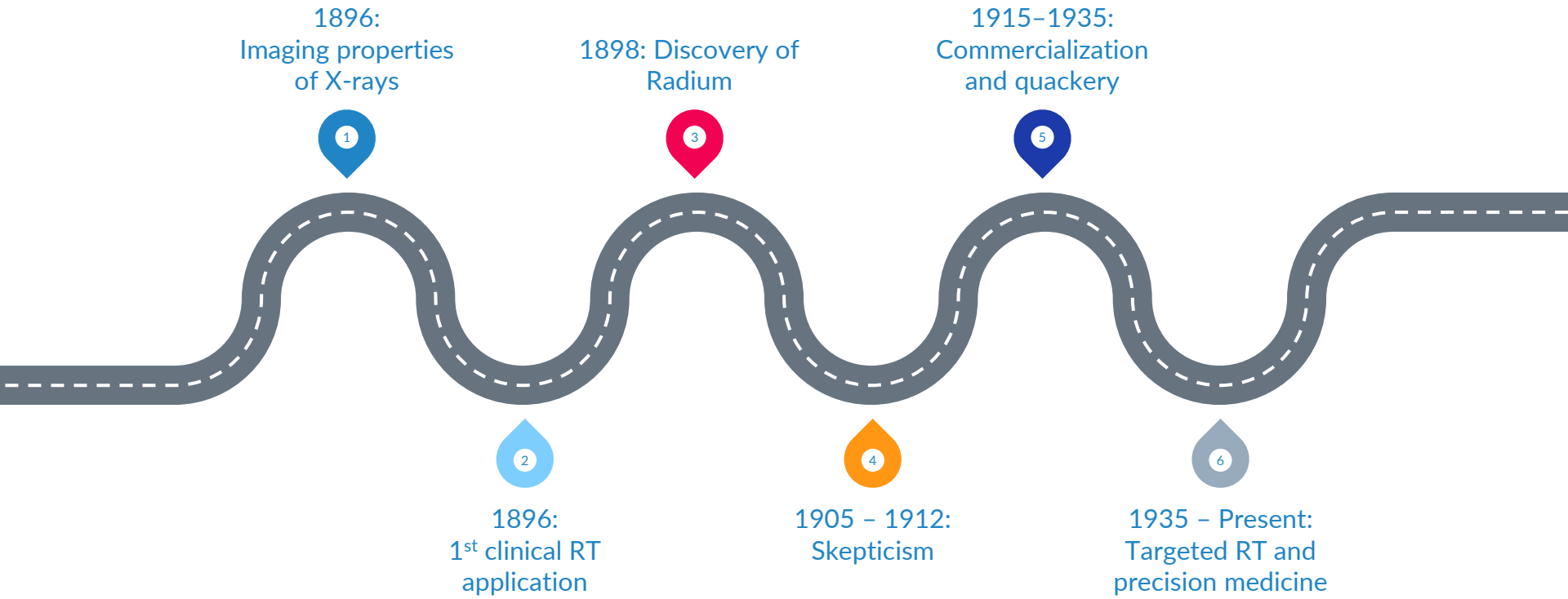
OBJECTIVES

1. Introduction and history of radiation therapy (RT)
2. Physical and Biological basis for radiation
3. Clinical applications of RT in the management of cancer
4. RT team and process – simulation, treatment planning, delivery
5. Types of RT

1.

INTRODUCTION AND HISTORY OF RT

HISTORY:


1896:
Imaging properties
of X-rays
1
1898: Discovery of
Radium
3
1915–1935:
Commercialization
and quackery
5
2
1896:
1st clinical RT
application
4
1905 – 1912:
Skepticism
6
1935 – Present:
Targeted RT and
precision medicine

- RT: use of high doses of radiation to kill cancer cells and shrink tumors.
- RT has been an effective tool for treating malignancies for 100+ years
- More than 60 % of patients diagnosed with cancer will receive radiation therapy as part of their treatment
- RT damages the DNA of cancer cells
- Lifetime dose limitations!

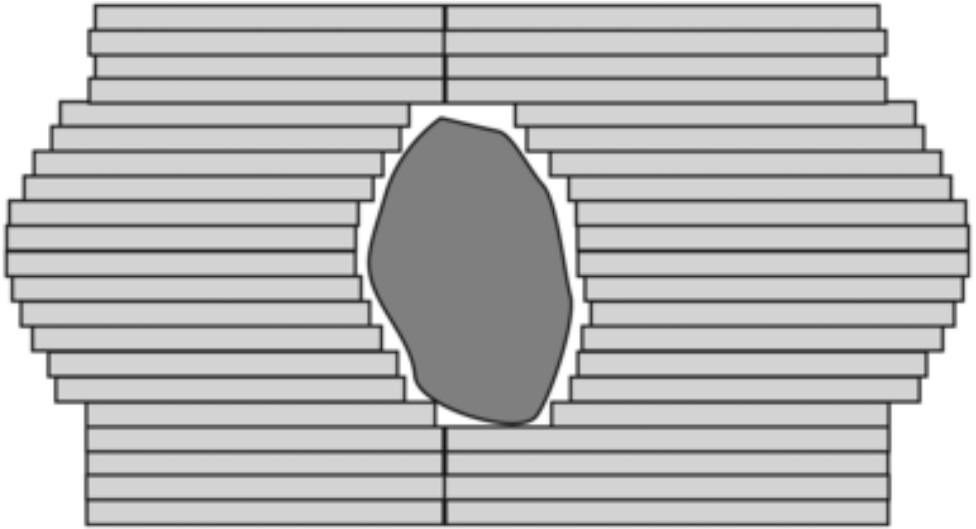
2.

RADIOBIOLOGY AND PHYSICS

BIOLOGY BASICS OF RT:

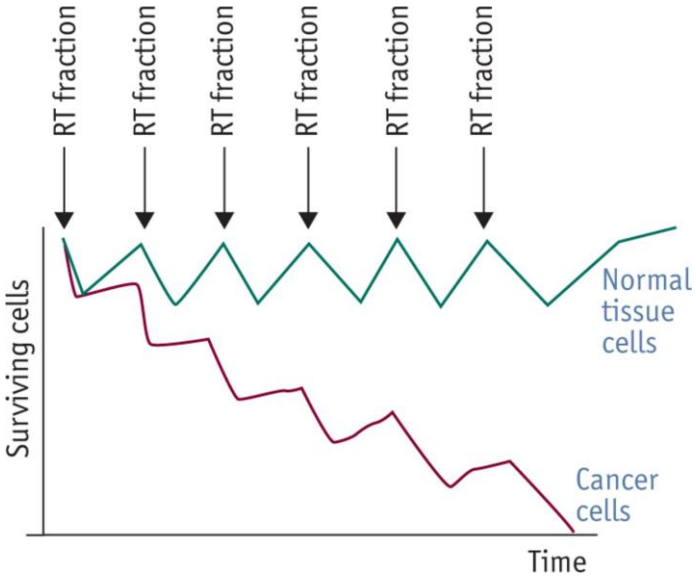
- RT: works by damaging the DNA of cells and destroys their ability to reproduce
- Both normal and cancer cells can be affected by radiation, but cancer cells have generally impaired ability to repair this damage, leading to cell death
- All tissues have a tolerance level, or maximum dose, beyond which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

PHYSICS OF RT:



- The linear accelerator accelerates electrons using microwave technology to almost light-speed
- Electrons collide with a heavy metal target, producing high-energy X-rays from the target
- High-energy X-rays are shaped as they exit the machine to conform to the shape of the tumour, and the shaped beam is directed to the tumour

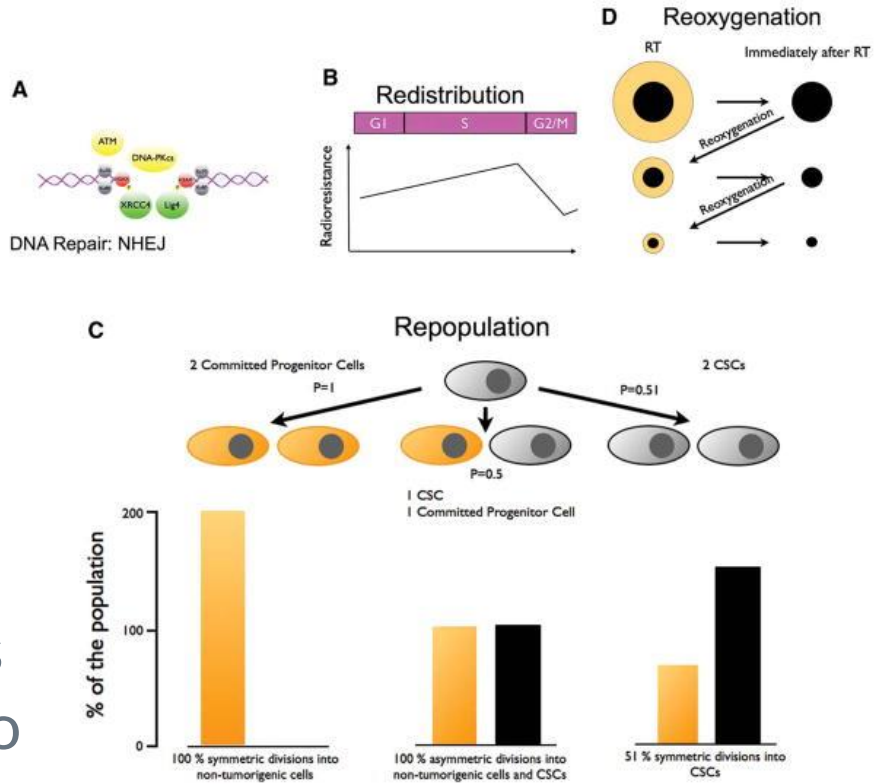
FRACTIONATION:



- 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
- Unit used for absorbed dose is the gray (Gy)
- Dose is prescribed as Gy per # (fractions)

FOUR R'S OF RADIOBIOLOGY:

- Repair of sublethal damage to cells between fractions
- Redistribution of cells into radiosensitive phases of cell cycle
- Repopulation or regrowth of cells between fractions
- Reoxygenation of hypoxic cells to make them more sensitive to radiation



3.
CLINICAL APPLICATION OF RT

2 MAJOR THERAPEUTIC FUNCTIONS:

- TO CURE CANCER:
  - Destroy tumors that have not spread
  - Kill residual microscopic disease left after surgery or chemotherapy
  - Reduce size of tumor prior to curative surgery
- TO REDUCE OR PALLIATIVE 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

RT BASICS:

- Delivery of external beam RT is painless and usually scheduled five days a week for one to ten weeks
- Effects are cumulative with most significant side-effects near the end:
  - Side effects usually resolve over the course of a few weeks
  - Slight risk that RT 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 RT SIDE-EFFECTS:

- Fatigue
- Breast – erythema, pruritus, desquamation
- Abdomen – nausea, vomiting, diarrhea
- Chest – cough, shortness of breath, esophageal irritation
- Head and neck – taste alterations, xerostomia, mucositis, dysphagia, odynophagia
- Brain – hair loss, scalp erythema, increased ICP symptoms
- Pelvis – diarrhea, urinary frequency, vaginal irritation
- Prostate – impotence, urinary symptoms, diarrhea

PALLIATIVE RT:

- Commonly used to relieve pain from bone cancers
  - ~ 50% of patients receive total relief from their pain
  - 80 to 90 %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
  - Multiple brain metastases

4.
RADIATION ONCOLOGY TEAM

RADIATION ONCOLOGY TEAM:

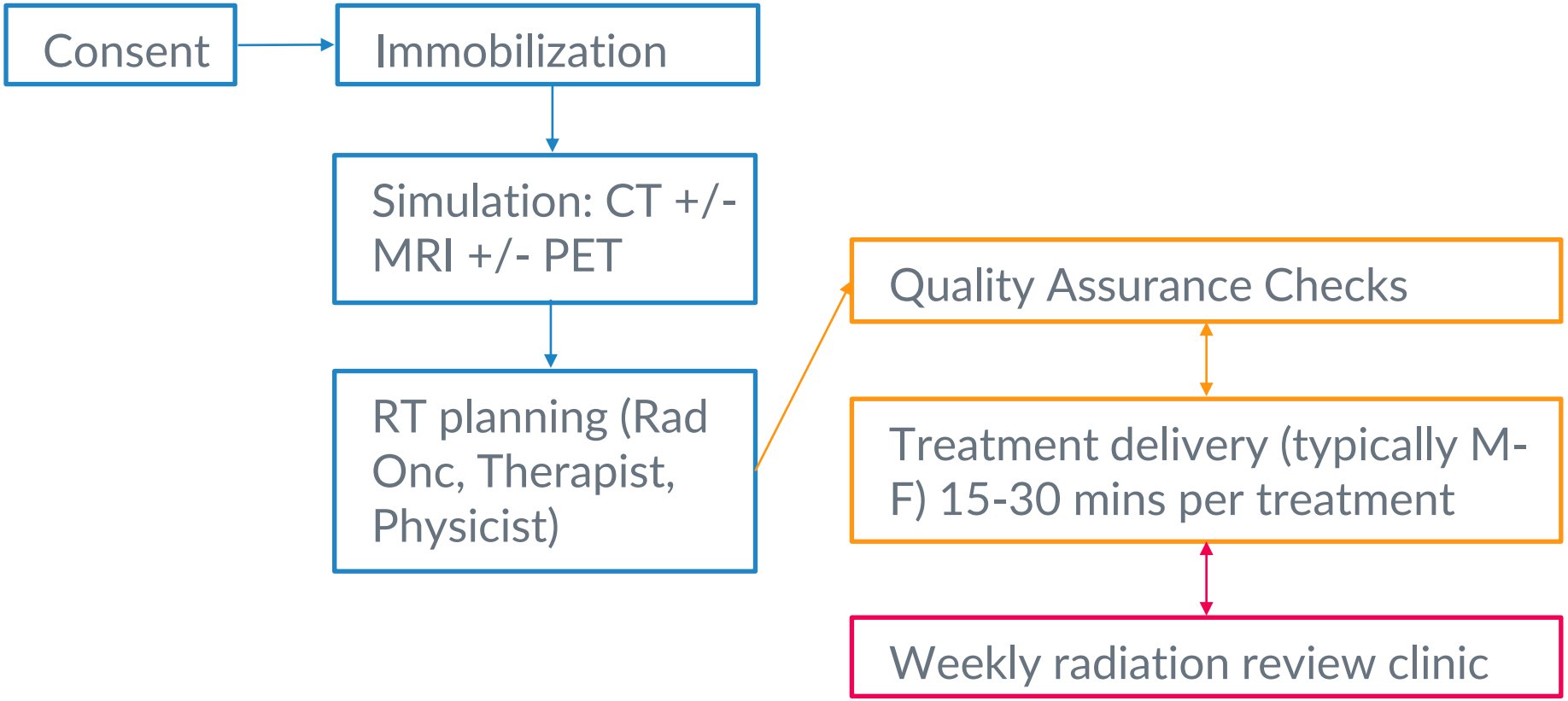
- **Radiation Oncologist:** specialist who prescribes and oversees the radiation therapy treatments
- **Medical Physicist:** ensures that RT plans are properly tailored for each patient, and is responsible for the calibration and accuracy of treatment equipment
- **Dosimetrist:** works with the radiation oncologist and physicist to calculate the proper dose of RT to deliver
- **Radiation Therapist:** administers the daily RT
- **Radiation Oncology Nurse:** interacts with the patient and family at the time of consultation, throughout the treatment process and during follow-up care

RADIATION ONCOLOGY APP:

- Physician Assistants and Nurse Practitioners:
  - Provide high quality patient care comparable to medical doctors and improving patient satisfaction
  - Provide team-based care
  - Provide treatment summary and survivorship care plan, assess treatment response, and address treatment-related effects
  - In-charge of care coordination, follow-up planning, and referrals
  - Most importantly, decrease wait times for access to care while providing quality care

4.
RT PROCESS

THE TREATMENT PROCESS:



REFERRAL:

- Referring physician has likely (**not always) discussed diagnosis with the patient
- New patient referral form, including:
  - Recent history and physical examination
  - Allergies, co-existing medical conditions, and current medications
  - History of previous malignancies and treatments
  - Pathology
  - Operative reports
  - Diagnostic imaging
  - Blood work
  - Other pertinent clinically information

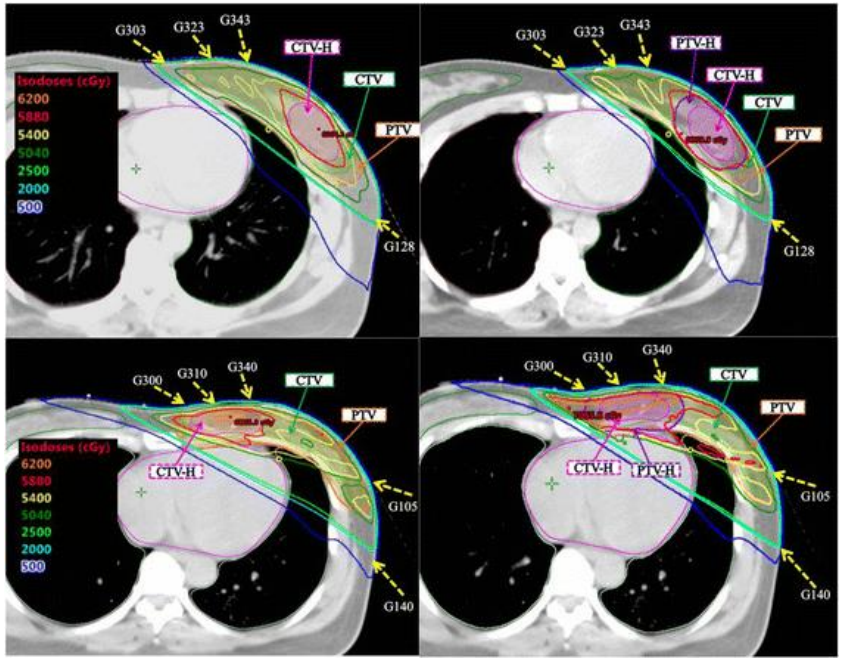
CONSULTATION:

- Radiation oncologist determines whether RT is appropriate
- Missing investigations are organized (pathology review, specialized imaging, other consultations)
- A treatment plan is developed and discussed
- Care is coordinated with other members of patient's oncology team
- Difficult cases are often discussed at multidisciplinary rounds to determine personalized care

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:



- RO/APP/CSRT outlines the target and organs at risk
  - Sophisticated software (i.e. RayStation) is used to carefully derive an appropriate plan, sparing as much healthy tissue as possible
  - Computerized algorithms enable the treatment plan to spare as much healthy tissue as possible
- Medical physicist reviews the chart and dose calculations
- Radiation oncologist reviews and approves final plan

SAFETY AND QUALITY ASSURANCE:

- Each radiation therapy treatment plan goes through many safety checks
  - Medical physicist checks the calibration of the linear accelerator on a regular basis to assure the correct dose is being delivered
  - 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
- IMPLICATION OF MISTAKES?

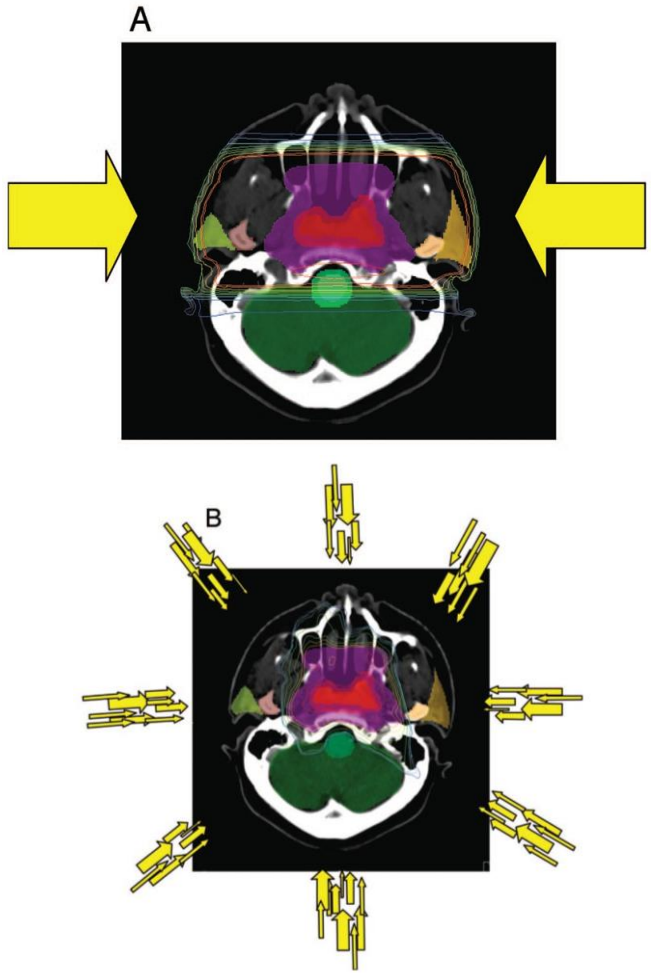
DELIVERY OF RT:

- External beam RT typically delivers radiation using a linear accelerator
- Internal RT, 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

5.
TYPES OF RT

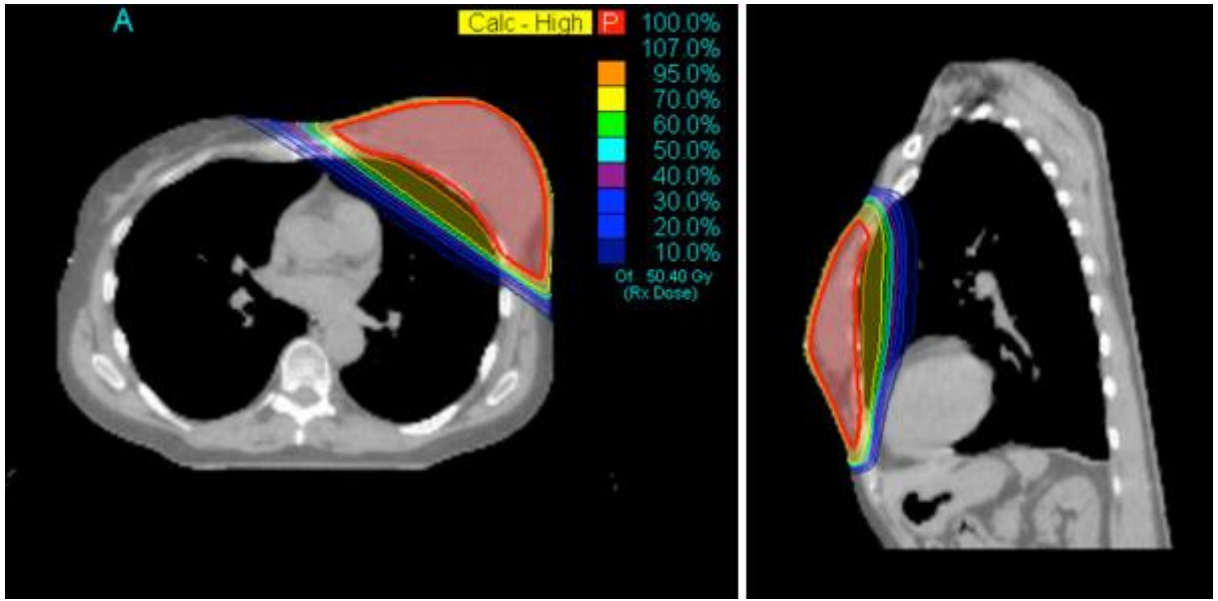
TYPES OF EBRT:

- Two-dimensional radiation therapy
- Three-dimensional conformal radiation therapy (3-D CRT)
- Intensity modulated radiation therapy
- Image Guided Radiation Therapy
- Intraoperative Radiation Therapy
- Stereotactic Radiotherapy
- Orthovoltage Radiotherapy
- Photon Therapy



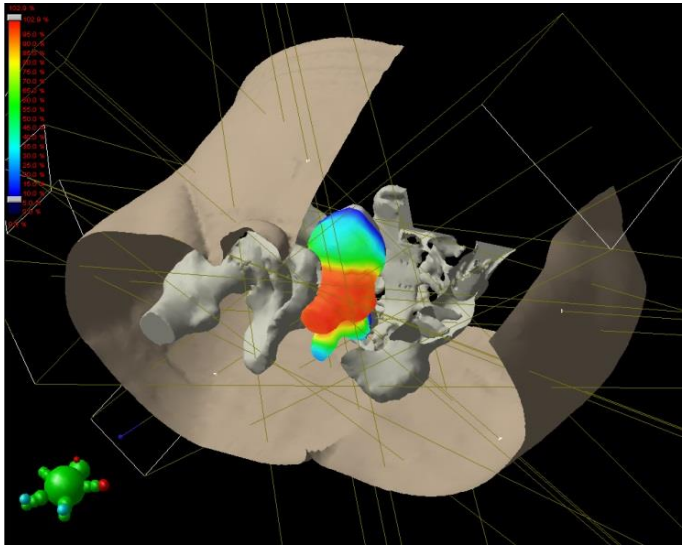
3-DIMENSION CONFORMAL RT (3D CRT):

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



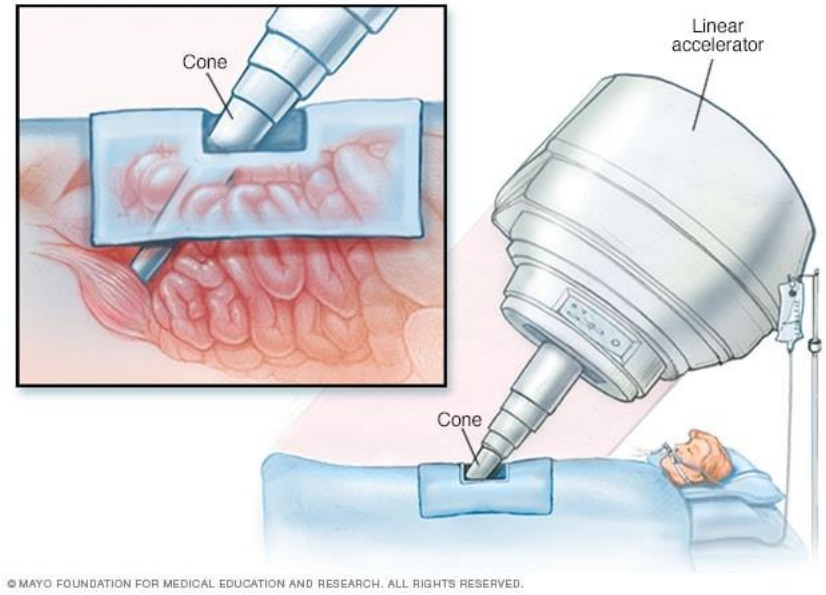
INTENSITY MODULATED RT (IMRT):

- 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 radiation to be delivered to the tumor while sparing more healthy surrounding tissue



INTRAOPERATIVE RADIOTHERAPY (IORT):

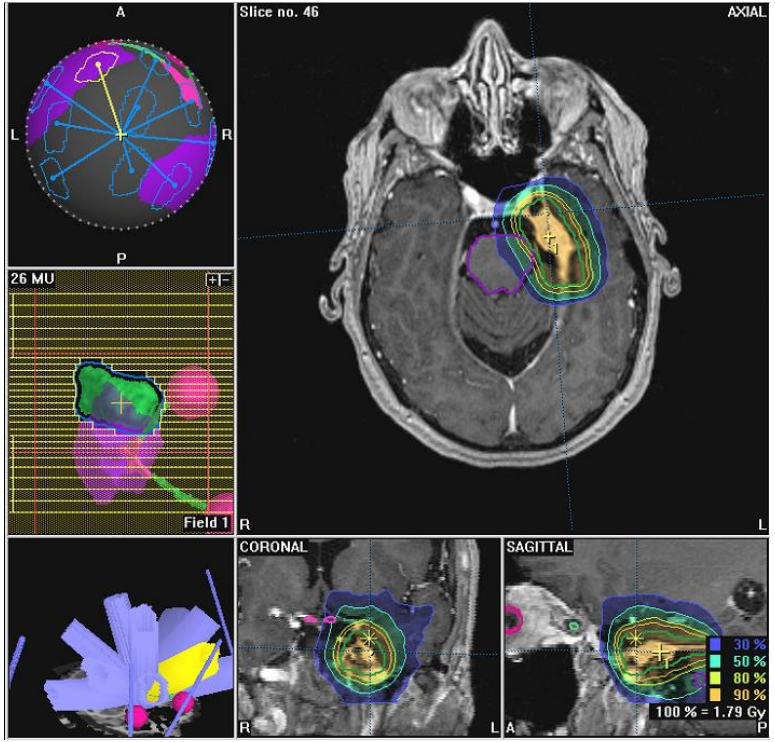
- IORT delivers a concentrated dose of radiation therapy to a tumor bed during surgery
  - Advantages
    - Decrease volume of tissue in boost field
    - Ability to exclude part or all of dose-limiting normal structures
    - Increase the effective dose



- Multiple sites Pancreas, stomach, lung, esophagus, colorectal, sarcomas, pediatric tumors, bladder, kidney, gyne
- Several recent trials have shown efficacy for breast cancer

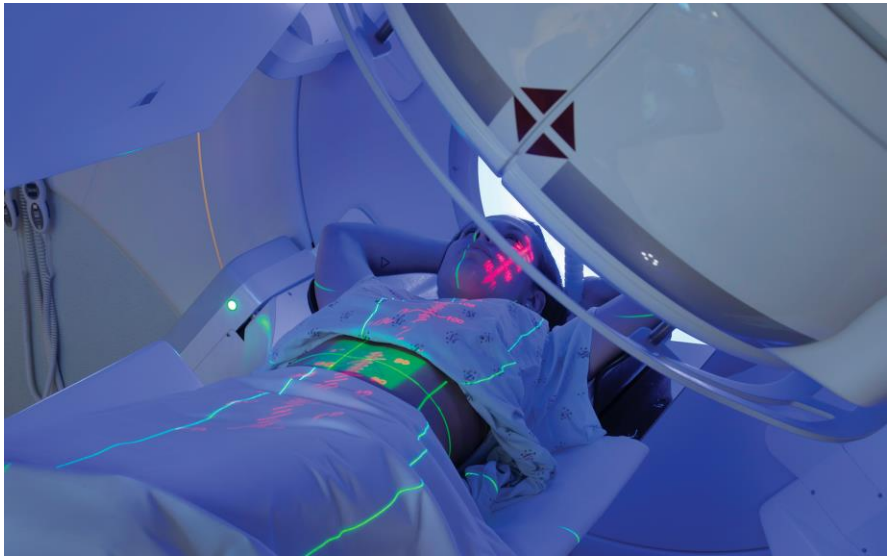
STEREOTACTIC RADIOSURGERY (SRS):

- 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):

- 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



ORTHOVOLTAGE TREATMENT:

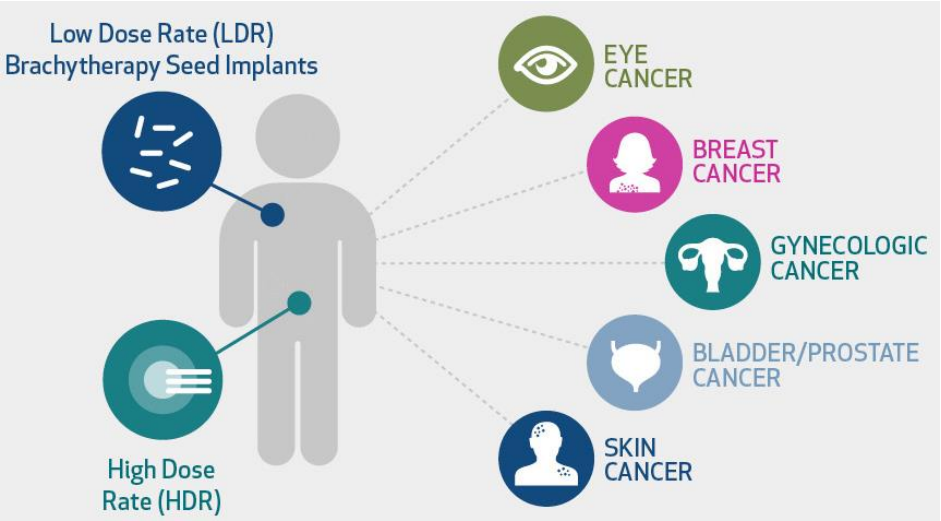
- Orthovoltage radiation treatments use lower x-ray energy than conventional RT
- Used for superficial lesions such as Keloids and skin cancers
- Orthovoltage requires about fifteen minutes a day for set up & Treatment is typically delivered between 10 - 30 #

PROTON 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

TYPES OF INTERNAL RT:

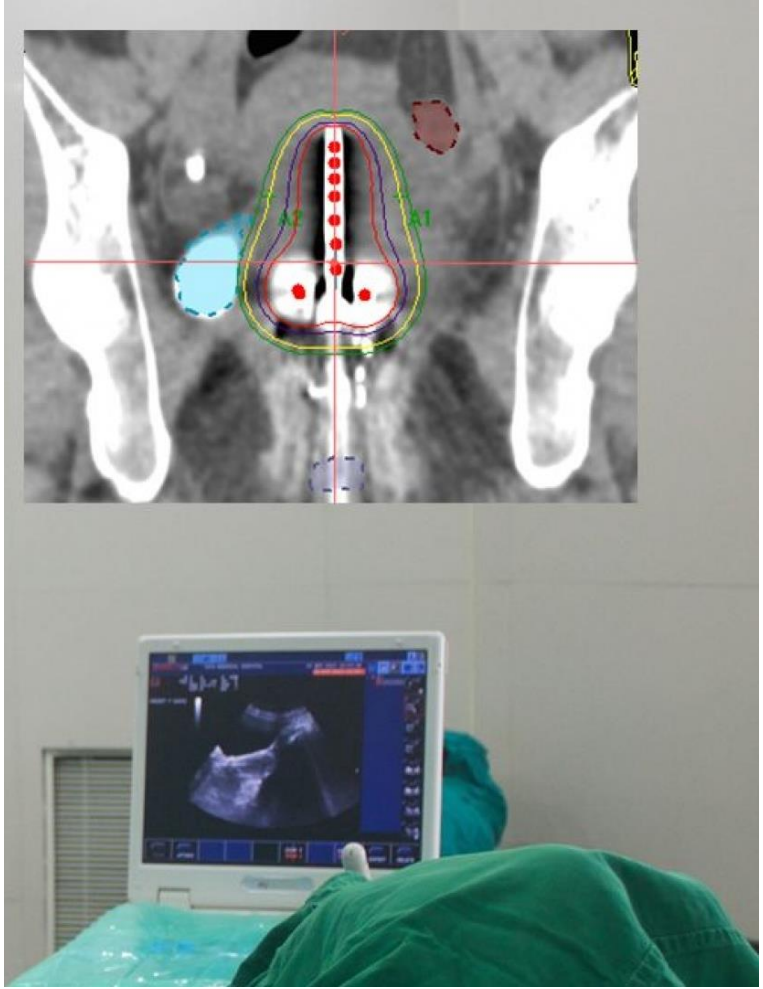
- Intracavitary implants
  - Radioactive sources are placed in a cavity near the tumor (breast, cervix, uterine)
- Interstitial implants
  - Sources placed directly into the tissue (prostate, vagina)



- Intra-operative implants
  - Surface applicator is in direct contact with the surgical tumor bed

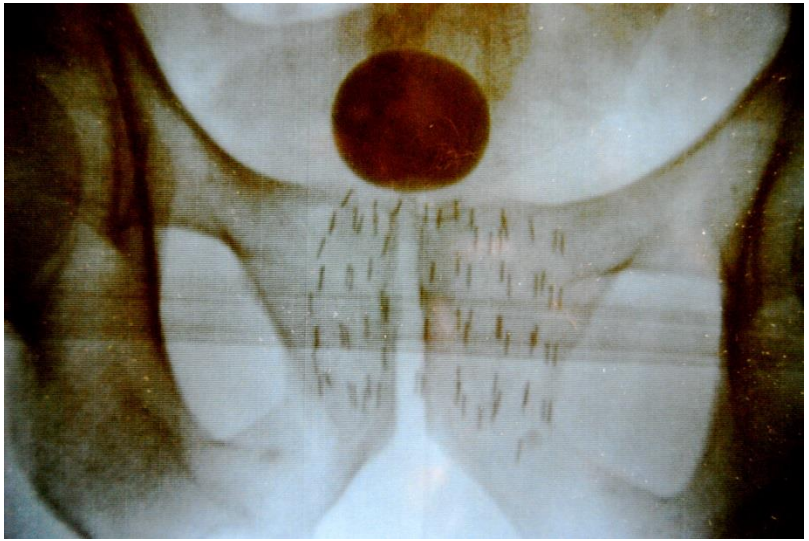
BRACHYTHERAPY:

- 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



BRACHYTHERAPY DOSE RATE:

- Low-Dose-Rate (LDR)
  - RT 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



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

SYSTEMIC RT:

- Radiation can also be delivered systemically:
  - ^{131}Iodine – to treat primary and metastatic thyroid caner
  - Metastron (^{89}Strontium), Quadramet (^{153}Samarium) and Xofigo (^{223}Radium) are radioactive isotopes absorbed 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

“Conquer Cancer in Our Lifetime”

Thank You!

Any questions?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