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UNC CANCER CARE

Introduction to Radiation Oncology

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September 18, 2019

Goals/Objectives

- Understanding the logistics of radiation treatments
- Understanding how radiation works
- Discussion of integration of multiple therapies for patients with cancer
- Introduction to different types of therapeutic radiation

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Outline

- **What is cancer and its impact?**
- How do we treat cancer?
- What is radiation?
- Case example
- Treatment planning examples

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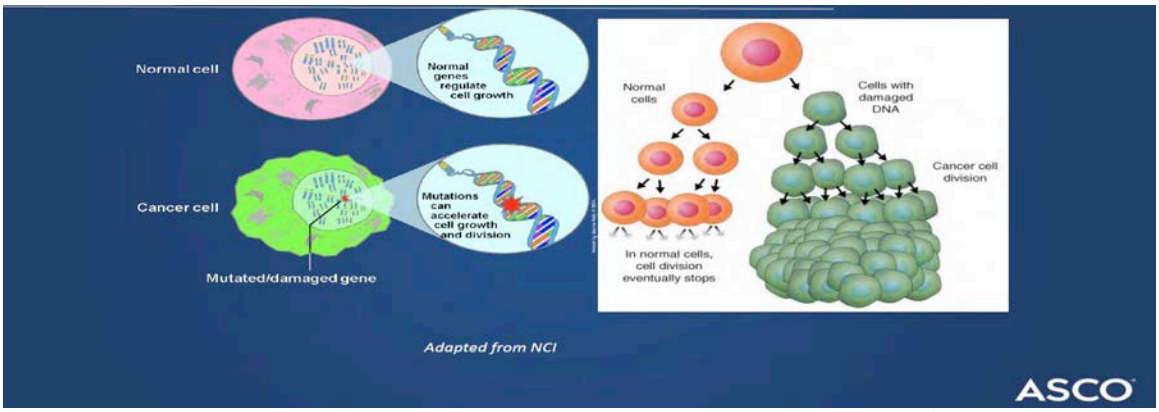
What is cancer?

- Hundreds of different diseases – all characterized by uncontrolled, abnormal growth of cells
- Cancer can cause local problems (from a tumor) or systemic problems (from metastasis)

Adapted from asco.org



Global impact of cancer

- In 2018 there were 17 million new cancer diagnoses, and 9.5 million cancer deaths worldwide.
- In 2030, this is anticipated to increase to 27.5 million new cases and 16.3 million deaths.

Global Cancer Facts & Figures 2018

- More than half of all cancer patients receive radiation treatments

Burnet NG, Thomas SJ, Burton KE, Jefferies SJ. Defining the tumour and target volumes for radiotherapy. Cancer Imaging. 2004;4(2):153-161.

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Cause of mortality in the US

- Heart disease 635,000
- Cancer 598,000
- Accidents 161,000
- Lung disease 154,000

CDC 2017

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Impact of cancer in the US

Figure 3. Leading Sites of New Cancer Cases and Deaths – 2019 Estimates

Estimated New Cases

Male			Female		
Prostate	174,650	20%	Breast	268,600	30%
Lung & bronchus	116,440	13%	Lung & bronchus	111,710	13%
Colon & rectum	78,500	9%	Colon & rectum	67,100	7%
Urinary bladder	61,700	7%	Uterine corpus	61,880	7%
Melanoma of the skin	57,220	7%	Melanoma of the skin	39,260	5%
Kidney & renal pelvis	44,120	5%	Thyroid	37,810	4%
Non-Hodgkin lymphoma	41,090	5%	Non-Hodgkin lymphoma	33,110	4%
Oral cavity & pharynx	38,140	4%	Kidney & renal pelvis	29,700	3%
Leukemia	35,920	4%	Pancreas	26,830	3%
Pancreas	29,940	3%	Leukemia	25,860	3%
All sites	**870,970**		**All sites**	**891,480**	

Estimated Deaths

Male			Female		
Lung & bronchus	76,650	24%	Lung & bronchus	66,020	23%
Prostate	31,620	10%	Breast	41,760	15%
Colon & rectum	27,640	9%	Colon & rectum	23,380	8%
Pancreas	23,800	7%	Pancreas	21,950	8%
Liver & intrahepatic bile duct	21,600	7%	Ovary	13,980	5%
Leukemia	13,150	4%	Uterine corpus	12,160	4%
Esophagus	13,020	4%	Liver & intrahepatic bile duct	10,180	4%
Urinary bladder	12,870	4%	Leukemia	9,690	3%
Non-Hodgkin lymphoma	11,510	4%	Non-Hodgkin lymphoma	8,460	3%
Brain & other nervous system	9,910	3%	Brain & other nervous system	7,850	3%
All sites	**321,670**		**All sites**	**285,210**	

Estimates are rounded to the nearest 10, and cases exclude basal cell and squamous cell skin cancers and in situ carcinoma except urinary bladder. Estimates do not include Puerto Rico or other US territories. Ranking is based on modeled projections and may differ from the most recent observed data.

Cancer Facts & Figures 2019

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Types of cancer treated with radiation

- Gastrointestinal
- Gynecologic
- Thoracic
- Lymphoma/Leukemia
- Genitourinary
- Sarcoma
- Head and Neck
- CNS
- Pediatric***

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Treatment of cancer

- Local therapy
  - Surgery
  - Radiation
- Systemic therapy
  - Chemotherapy
  - Hormonal therapy
  - Targeted therapy
  - Immunotherapy

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Overview of oncologic care – "cancer doctors)

Medical Oncology

(adult or pediatric)

Surgical Oncology

Neurosurgery, Cardiothoracic, Colorectal, Gynecologic, Orthopedic, Urology, Ophthalmology, Dermatology, etc.

Radiation Oncology

Adapted from ROECSG – Radiation Oncology Education Collaborative Study Group – Medical Student Curriculum

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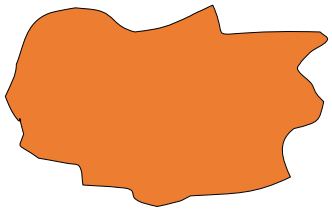
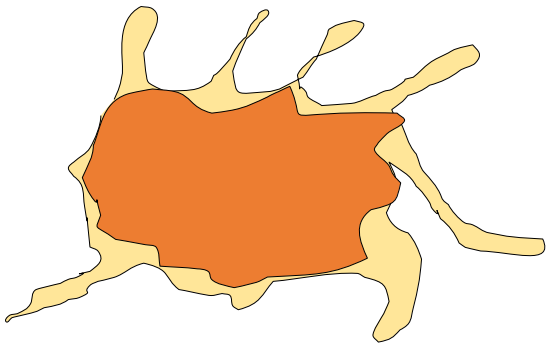
Cancer: local spread, local treatments



Grossly seen



Microscopic extensions

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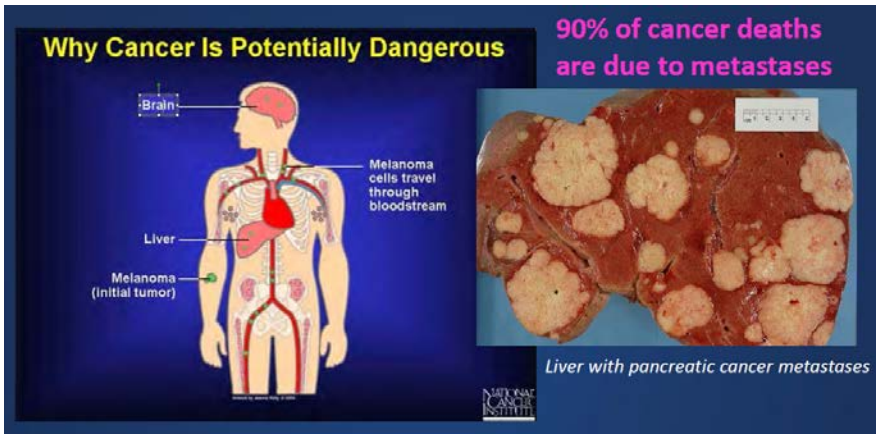
Cancer can spread outside of the initial organ = metastatic disease



Adapted from ASCO.org

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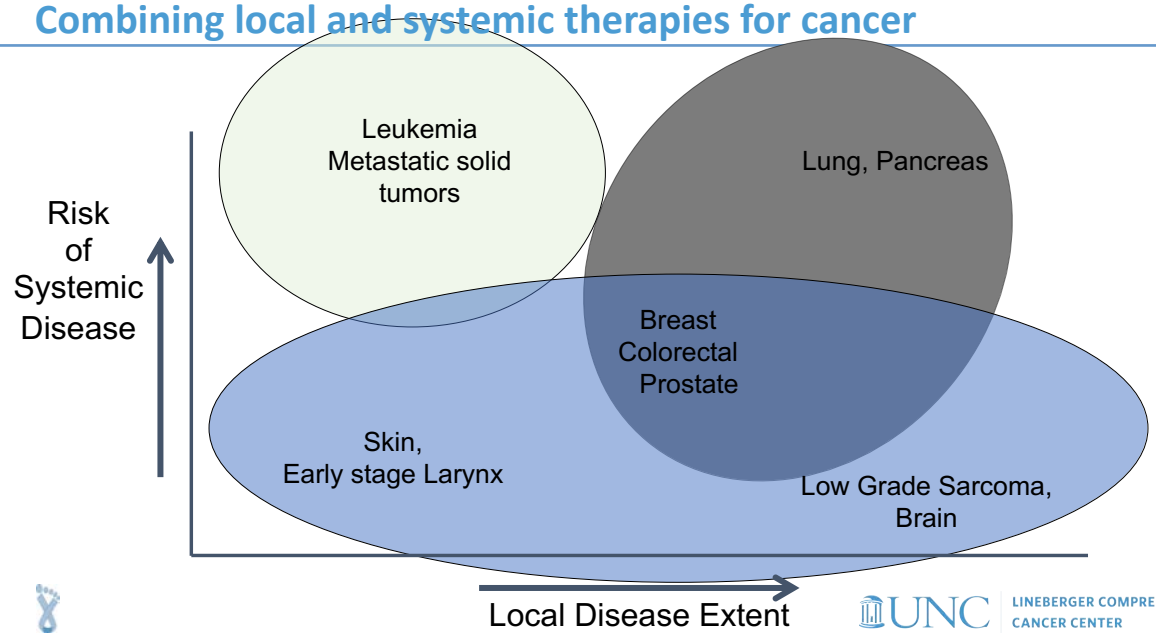
Combining local and systemic therapies for cancer



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Radiation is a local therapy

- Palliative – to help with a symptom (not curative)
  - Pain
  - Bleeding
  - Neurologic symptoms
- Definitive – curative intent without surgery
- Neoadjuvant – before surgery
- Adjuvant – after surgery

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How to choose local therapies (surgery, RT or both)

- Radiation may allow a smaller surgery
  - Breast – mastectomy vs partial mastectomy + RT
  - Extremity sarcoma – amputation vs wide local excision + RT
- Adjuvant RT (based on surgical findings)
  - Lung
  - H&N
  - Prostate
  - Brain
- Neoadjuvant RT (RT before surgery)
  - Rectal

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When is RT often used alone (instead of surgery) ?

Examples include:
Early or advanced head & neck cancer
Advanced cervical cancer
Prostate

Patients who are not candidates for surgery

Surgeries that would otherwise be too extensive

Cancers that outcomes are similar between radiation and surgery

Careful risk-benefit assessment

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Role of chemotherapy

	Radiosensitization	Systemic Therapy
Breast		✓
Colorectal	✓	✓
Cervix	✓	
Head & Neck	✓	
Lung	✓	✓

Emerging roles of immunotherapy and targeted therapies!

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Radiation Therapy: Brief History

- 1895 Roentgen discovers x-rays
- 1896 First diagnostic x-ray
  - locate piece of knife from stabbing
- 1897 Fruend treats patient with hairy mole
- 1898 Curies report discovery of radium
- 1898 Becquerel discovers radioactivity
- 1922 Coutrard/Hautant report cure larynx cancer

- From Hall (Radiobiology for Radiobiologists), Halperin, Perez and Brady

Early Roentgen image January, 1896.

Radioactivity

- 1896 - Henri Becquerel
- experimenting with uranium salts
- photographic plate exposed
- Discovered *radioactivity* while experimenting with uranium salts which exposed a photographic plate
- Pierre and Marie Curie discover radium and polonium in 1898
- These elements emitted α, β and γ *rays*

Becquerel's photographic plate fogged by radiation from uranium salts.

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X-rays and Gamma Radiation

- Both are forms of *ionizing* radiation
- X-rays and γ-rays both *photons*
  - X-ray: *people-made*: electron strikes target
  - γ-rays : nuclear decay (can be naturally occurring)

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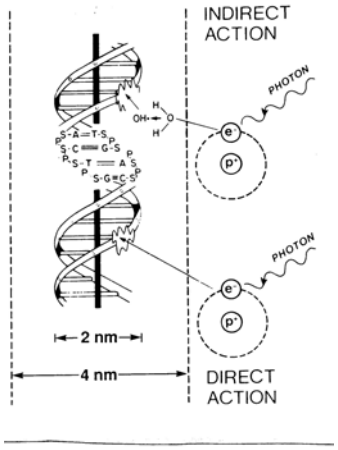
Radiation kills cancer cells by DNA damage



- Normal cells can repair DNA damage
- Cancer cells are geared only to grow and spread and cannot effectively repair DNA damage
- Cancer cells then eventually die = mitotic catastrophe

From Eric Hall

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Fractionating can make radiation safer for normal tissues

- Fractionating = many small doses of radiation instead of fewer larger dose
- Rapidly growing tissues
  - Tumors and some normal tissues (mucosa, marrow, skin)
  - Still are impacted in terms of efficacy (tumor) or side effect (normal tissue) with fractionating
- Slowly growing tissues
  - Many critical normal tissues (lung, brain, muscle, nerve, blood vessels).
  - Have much fewer side effects with fractionation

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Dose and fractionation

- Radiation dose is measured in the unit Gray (Gy)
- Dose varies based on treatment site, type of tumor, other therapies
- Typically delivered 5 days per week (M-F) for up to 7 weeks
- Usually the dose is 1.8-2.0 Gy per day (many exceptions)

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Linear accelerator – "standard" radiation treatment machines

http://info.oncologysystems.com/average-lifespan-elekta-linear-accelerator-parts/

CyberKnife – specialized for radiosurgery

Gamma Knife – specialized for brain radiosurgery

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Brachytherapy – implanted radiation

- Procedure based radiation technique
- Can involved implanted seeds (that remain in place indefinitely)
- Can involved temporary catheters (that are removed after radiation treatment)

- Sites
  - Prostate
  - Cervix
  - Endometrial
  - Breast
  - Esophageal
  - Sarcoma
  - Skin

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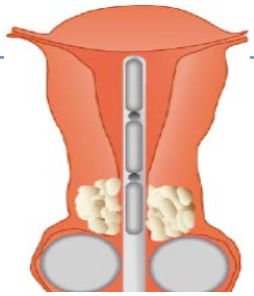
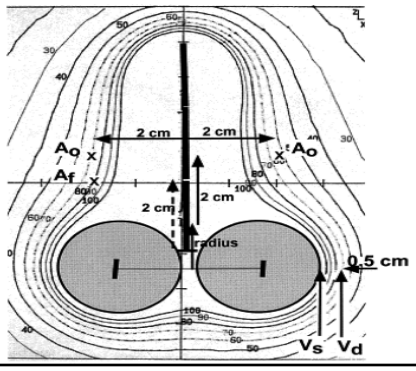
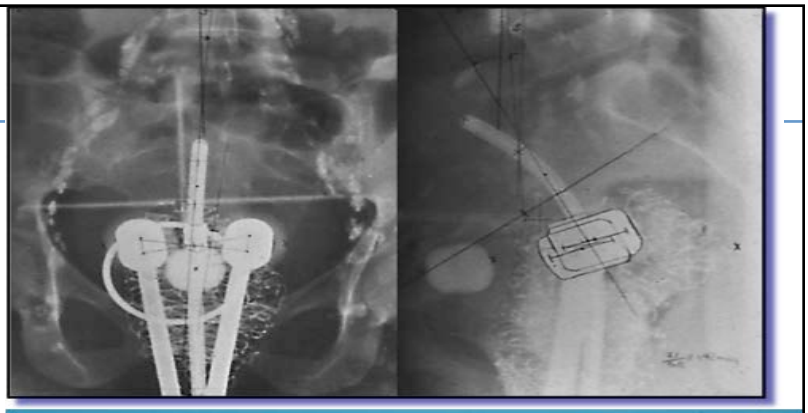
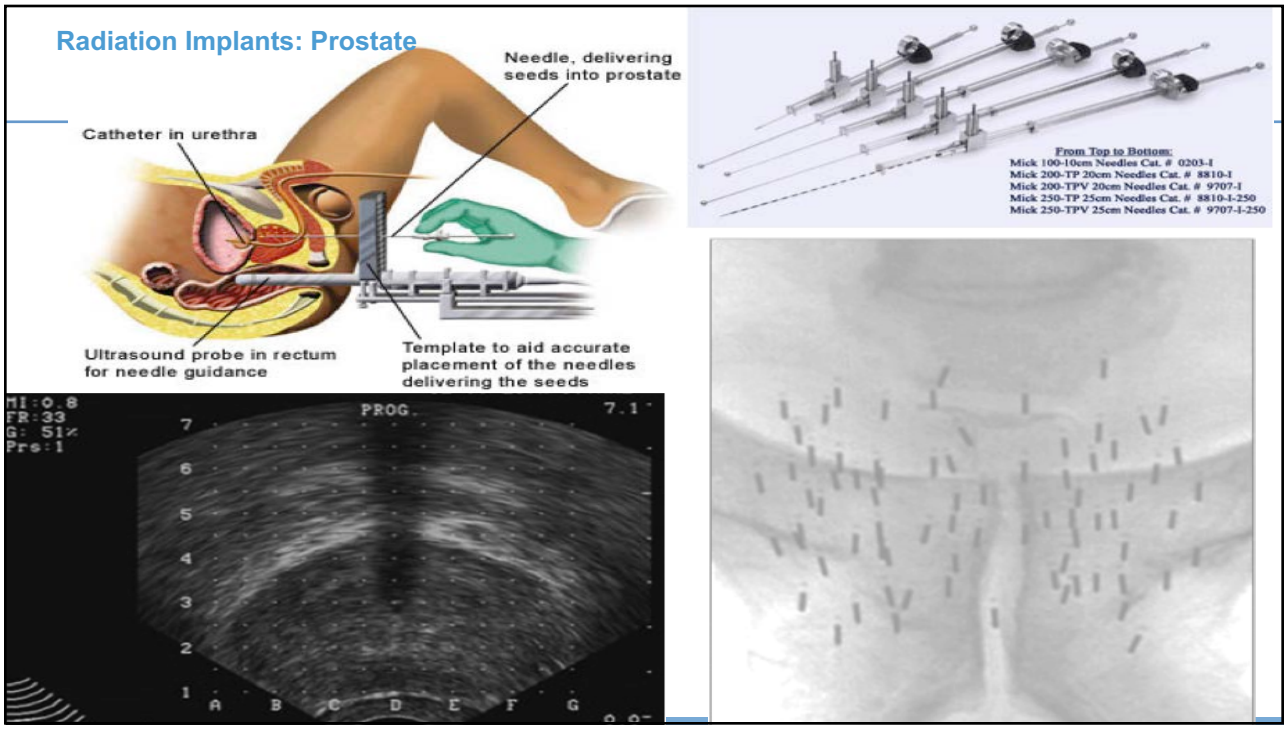
Radiation Implants: Uterine Cervix







Radiation Implants: Prostate



Intraoperative Radiation

Outline

- What is cancer and its impact?
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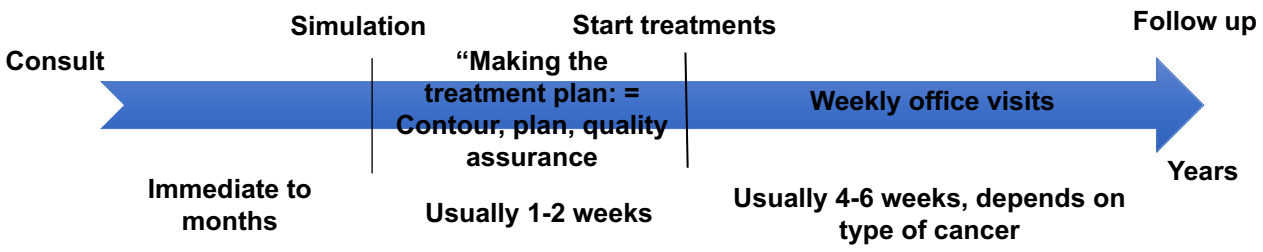
Timeline for a patient



Adapted from ROECSG – Radiation Oncology Education Collaborative Study Group – Medical Student Curriculum

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Case

- 57 y/o female presents to PCP with cough and shortness of breath for the past 6 weeks
- 25 lb weight loss
- Current smoker, 2 packs per day x 30 years
- Physical Examination: decreased breath sounds in upper right lung
- Chest x-ray – right upper lobe lung mass

Concerning for lung cancer

Adapted from ROECSG – Radiation Oncology Education Collaborative Study Group – Medical Student Curriculum

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Diagnostic Tests

- Biopsy (gives a cancer diagnosis)
- Staging
  - How large is the tumor?
  - Where is the tumor located?
  - Has the tumor spread?

BOTH biopsy and staging are needed to develop a treatment plan

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Diagnostic Tests and Treatment

- Biopsy – guided with a CT scan OR by bronschoscopy
- Staging imaging –
  - PET-CT
  - Brain MRI
- For this patient – biopsy is adenocarcinoma, staging shows the known right upper lobe mass, mediastinal lymph nodes. No disease outside of the chest. Stage III non-small cell lung cancer
- TREATMENT: 30 radiation treatments, concurrent chemotherapy, adjuvant immunotherapy

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What does the radiation oncologist do in clinic?

- Full and extensive history and physical relating to cancer diagnosis
- Although you are treating the tumor, knowing your patient's other medical problems and "performance status" will help you care for them

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What do radiation oncologists think about during initial consult?

- History: full and detailed in chronologic order. Include presenting symptoms, work-up, any staging studies and pertinent laboratories
- Past medical/surgical history
  - **Prior radiation treatment (breast cancer and prior Hodgkin's)
  - **Pacemaker or ICD
  - **Pregnant?
  - **Prior chemotherapy
  - **Connective tissue disorders
  - **Family history: **full family cancer history
- Social history: family, plans for future children?, employment, **living situation/location**, support structure, smoking, substance abose

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What do radiation oncologists think about during initial consult?

- Physical exam
  - Complete physical exam (focused)
  - More extensive exam of pertinent anatomical regions
    - Breast
    - Prostate
    - Glioblastoma
    - Bone metastasis
    - Lung
  - Performance status – how is the patient doing in terms of completing daily tasks, working, etc

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Performance Status

Karnofsky Performance Score

- **100% – normal, no complaints, no signs of disease**
- **90% – capable of normal activity, few symptoms or signs of disease**
- **80% – normal activity with some difficulty, some symptoms or signs**
- **70% – caring for self, not capable of normal activity or work**
- **60% – requiring some help, can take care of most personal requirements**
- **50% – requires help often, requires frequent medical care**
- **40% – disabled, requires special care and help**
- **30% – severely disabled, hospital admission indicated but no risk of death**
- **20% – very ill, urgently requiring admission, requires supportive measures or treatment**
- **10% – moribund, rapidly progressive fatal disease processes**
- **0% – death.**

ECOG/Zubrod

- 0 – Asymptomatic (Fully active, able to carry on all predisease activities without restriction)
- 1 – Symptomatic but completely ambulatory (Restricted in physically strenuous activity but ambulatory and able to carry out work of a light or sedentary nature. For example, light housework, office work)
- 2 – Symptomatic, <50% in bed during the day (Ambulatory and capable of all self care but unable to carry out any work activities. Up and about more than 50% of waking hours)
- 3 – Symptomatic, >50% in bed, but not bedbound (Capable of only limited self-care, confined to bed or chair 50% or more of waking hours)
- 4 – Bedbound (Completely disabled. Cannot carry on any self-care. Totally confined to bed or chair)
- 5 – Death

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What do radiation oncologists think about during initial consult?

- Assessment
  - *Always* stage the patient
    - Early breast — pT1bN0M0 Stage IA
    - Intermediate-risk prostate — cT2bN0M0, PSA 14.5, GS 3+4
    - Glioblastoma multiforme — WHO grade IV
    - Bone metastasis from lung — cT3N3M1 Stage IV
    - Lung Cancer — cT3N3 Stage III
- Plan
  - Could involve surgery, systemic therapy, RT
  - Does not always involve RT!!

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Proceeding with radiation treatments

- Simulation = CT scan
  - Determined by MD:
    - How to position the patient
    - What part of the body to scan
    - Contrast (yes/no)
    - Respiratory gating (yes/no)
  - Patient is set-up, scanned, and marked (tattoo) by radiation therapists

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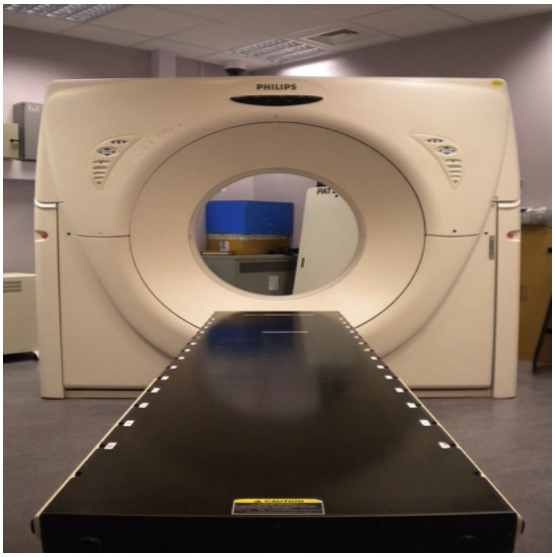
CT Simulation



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Treatment Planning

- MANY steps involved
  - Drawing targets
  - Designing fields
  - Creating radiation plan (dose)
  - MULTIPLE quality assurance steps
- Involved multiple people
  - Radiation oncologist
  - Dosimetrists
  - Medical physicists

Adapted from ROECSG – Radiation Oncology Education Collaborative Study Group – Medical Student Curriculum

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Treatment delivery

Adapted from ROECSG – Radiation Oncology Education Collaborative Study Group – Medical Student Curriculum

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Side effects of radiation

- Fatigue
- Otherwise depends on treatment site/volume (and chemotherapy) – where the radiation is pointed!
- Stage III lung
  - Acute (short-term)
    - Esophagitis – "sticking" sensation when swallowing, pain with swallowing
  - Chronic (long-term)
    - Radiation pneumonitis – lung inflammation
    - Pericarditis – inflammation of the lining of the heart
    - Cardiovascular disease – due to radiation the heart and coronary arteries
    - Secondary malignancy

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Other radiation side effects – where the beam is aimed!

- Pelvis – diarrhea, dysuria, bowel obstruction, ulceration, menopause, erectile dysfunction
- Brain – nausea, headache, radiation necrosis, memory problems
- Breast – skin irritation, scar tissue, brachial plexus injury
- H&N – dry mouth, irritation inside mouth, skin irritation

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Outline

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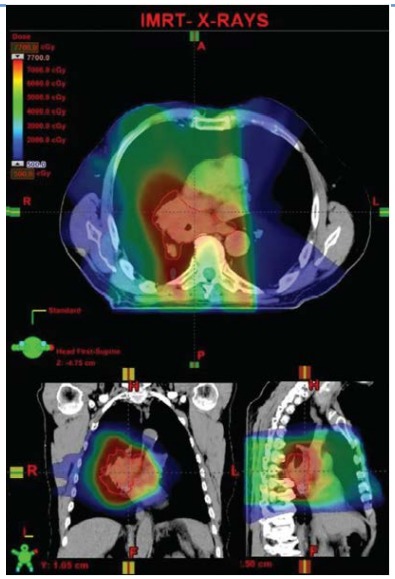
Treatment planning - lung



- Cover target (tumor + margin with desired dose
- Spare organs at risk
  - Spinal cord
  - Esophagus
  - Heart
  - Normal lung

Image from: Translational Oncology Research, Vol 1, No 4, Dec 2012.

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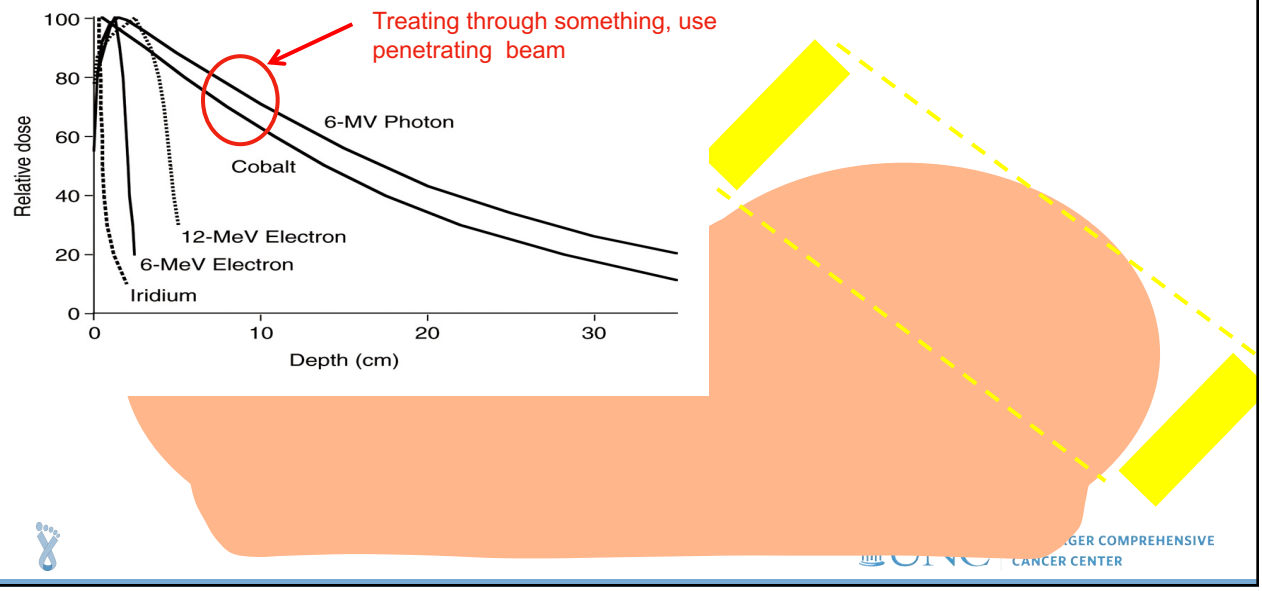
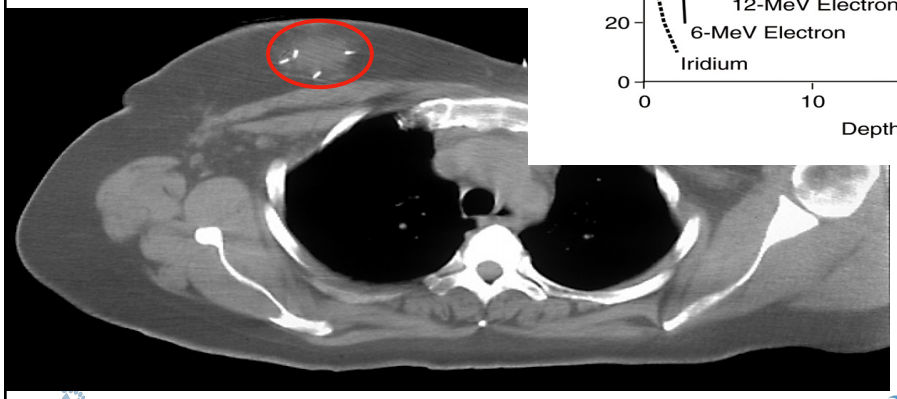
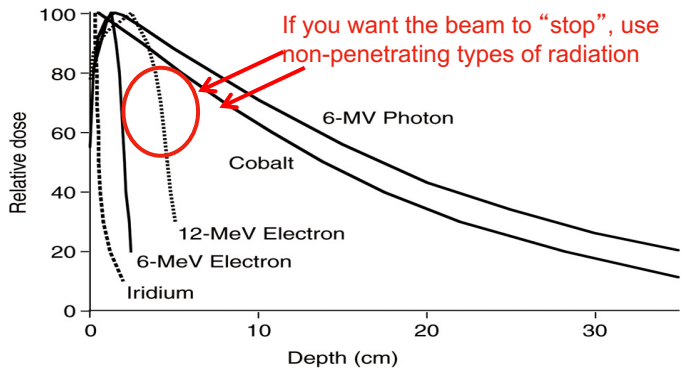
Tangents Photons

Treatment planning - breast



Treatment planning – breast boost





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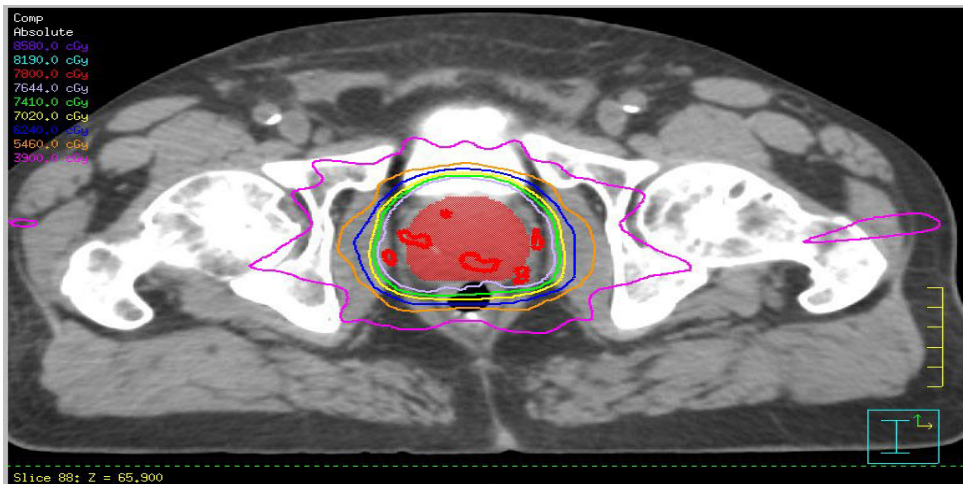
Treatment planning - prostate



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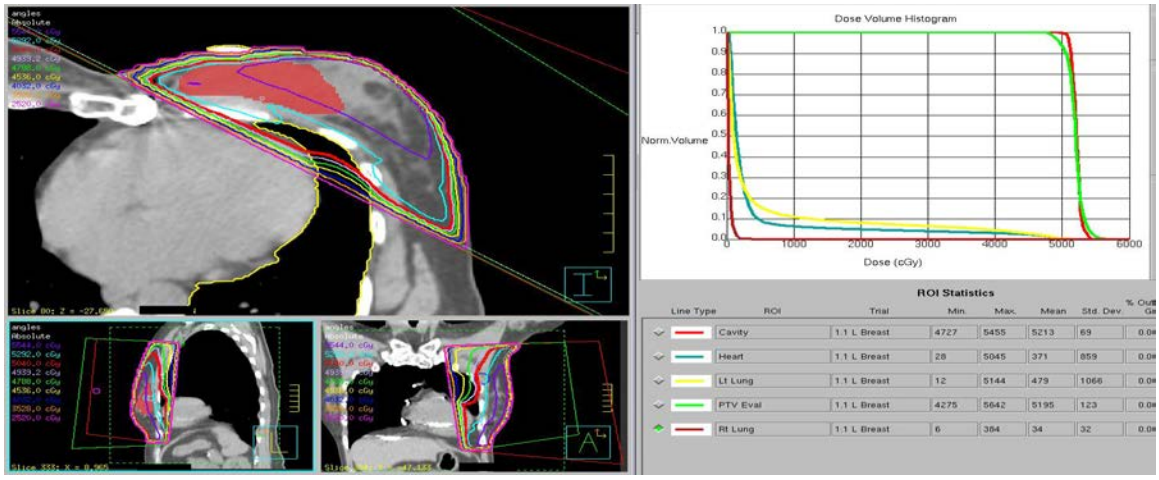
Treatment planning - breast



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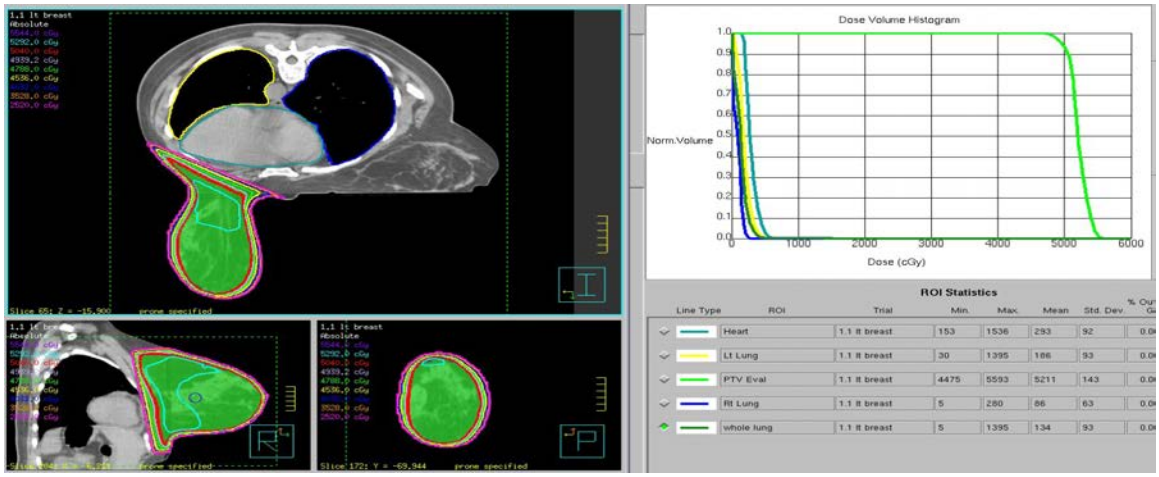
Treatment planning – prone breast



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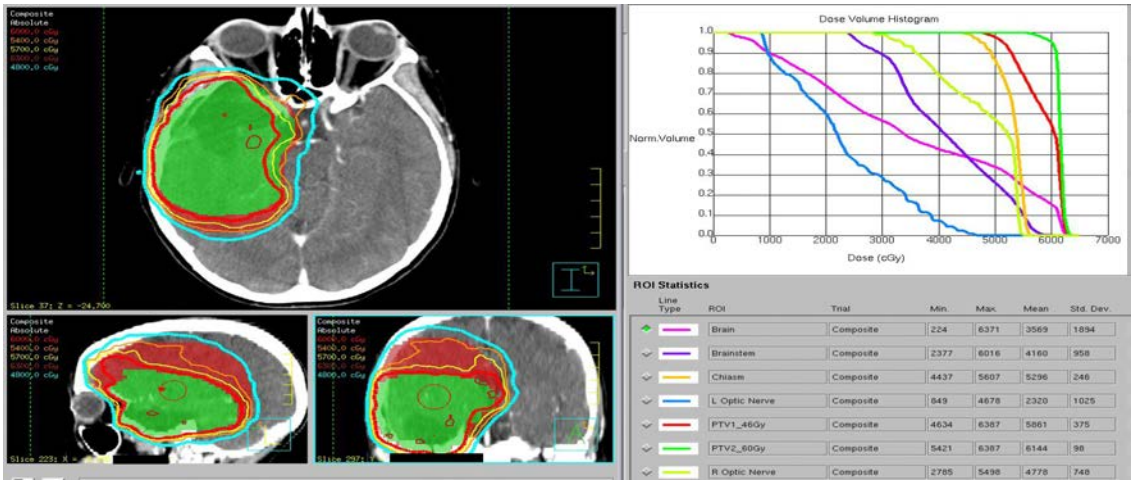
Treatment planning - brain



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Radiosurgery/Stereotactic Body Radiotherapy

- Specialized technique
  - High RT dose per fraction
  - Tight margin
  - Image guidance
  - Localization at time of treatment

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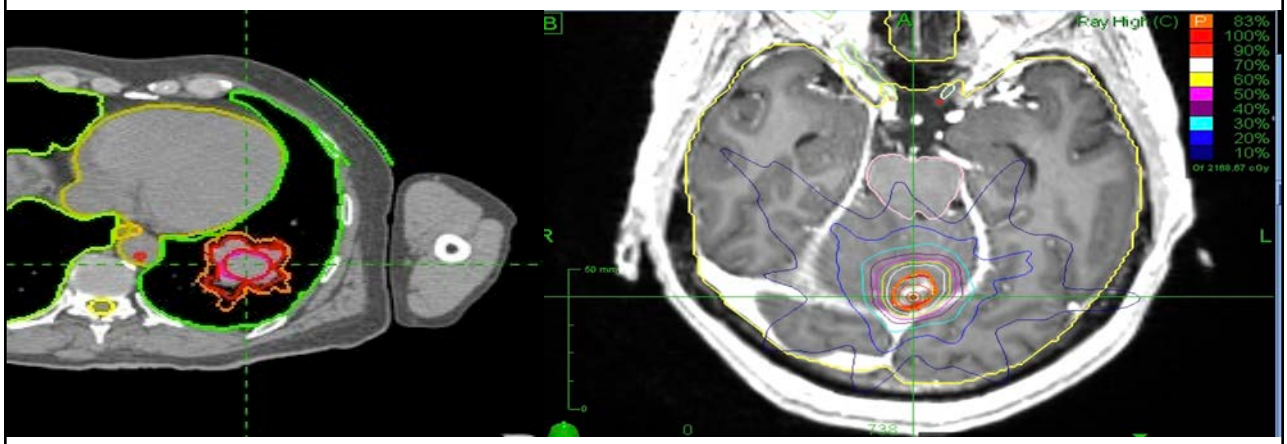
Radiosurgery



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Summary

- Oncologic care is complicated and requires a team
- Radiation can be used alone to cure cancer, or with other modalities
- The use of Radiation/Surgery/Chemo depends on:
  - The cancer's behavior; i.e. its likelihood to spread locally vs distantly, and
  - The functional impact of surgery vs RT as the local therapy
- Radiation works by causing damage to the DNA.
- There are many types of radiation techniques
  - External beam radiation (x-rays or electrons)
  - Radiosurgery
  - Brachytherapy
  - Intraoperative radiotherapy
- The job of the radiation oncologist includes working with a multidisciplinary team, selecting and designing RT treatments (ANATOMY!), managing treatment toxicities.

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References

- Some slides courtesy of
  - Dr. Larry Marks
  - Dr. Jessica Wilson
  - ROECSG (Radiation Oncology Education Collaborative Study Group)
- Other references:
  - ASCO.org – Oncology 101
  - ASTRO.org – Overview of RT for Healthcare Professionals
  - ASTRO.org – Radiation Oncology for Medical Students
  - Gunderson and Tepper, Clinical Radiation Oncology, 4th ed

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