The Role of Radiation Oncology in Cancer Care

Goals of this Lecture:

• What is therapeutic radiation
• How is it used in medicine
• What patients are candidates for radiation
• How is radiation planned and delivered
• What is a Radiation Oncologist
The Role of Radiation Oncology in Cancer Care

Lecture Outline

- The radiation oncology team
- Goals of radiation therapy
- The radiobiology of cancer
- Planning & delivering radiation treatment
- Case presentations
- Side-effects of radiation therapy
Radiation Therapy Team

- Radiation Oncologist
  - Medical Physicist
  - Radiation Therapist
  - Medical Dosimetrist
  - Oncology Nurse
Medical Physicist
Goals of Radiation Therapy

• Curative intent
  – Radiotherapy alone
  – Chemoradiation
  – Adjuvant radiation following surgery
  – Trimodality therapy

• Palliation
Curative: Radiotherapy Alone

- Prostate cancer
- Head & neck cancer
- Skin cancer
- Lung cancer
- Hodgkin’s disease
- Benign disease: keloid, desmoid, heterotopic bone
Curative: Chemoradiation

- Organ preservation
  - Esophagus
  - Bladder cancer
  - Head & neck
- Stage III non small cell lung cancer
- Small cell lung cancer
- Cervical cancer
- Hodgkin’s and NonHodgkin’s lymphoma
Curative: adjuvant Radiotherapy (Microscopic Residual Disease)

- CNS malignancies
- Sarcoma
- Head & neck malignancies
- Endometrial cancer
- Cervical cancer
- Non small cell lung cancer
Curative: Trimodality Therapy

- Breast
- CNS: anaplastic oligodendrogliomas, GBM
- Lung: Pancoast tumors
- Stage III lung cancer: under investigation
- Esophagus: under investigation
- Pancreas, colon
- Rectal cancer
Palliation

• Goals:
  – Relieve pain
  – Prevent fracture
  – Change the manner of death to that which is more acceptable to the patient and her family

• All metastatic sites
• High dose palliation; Unresectable disease
• Retreatment
What is Radiation?

The emission and propagation of energy through space or a material medium by electromagnetic waves or particles.
The Electromagnetic Spectrum

- Frequency $\times$ Wave Length = Speed of light
- Higher frequency means higher energy photons
- The higher the energy photon the more penetrating is the radiation
Radiobiology of Cancer

- DNA double strand breaks (DSB) are most important lesions caused by radiation.
- Two DSB may result in cell kill at the time of cell division, mutation or carcinogenesis.
- 6.9 Gy to kill 1 log of cells, therefore tumor with $10^9$ cells would require 10 logs of cell kill to $= 90\%$ chance control $= 69$ Gy.
DNA as THE Target

Irradiation of Chinese hamster cells by α particles from a polonium-tipped microneedle
How Do the Cells Die?

Apoptotic Death

Vs.

Mitiotic Death
Radiation Inflicts DNA Damage
Radiation Induced Chromosome Damage

Translocation

Dicentric

Ring

Deletion
The "4 R's" of Radiation Biology

Repair
Reassortment
Repopulation
Reoxygenation
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Therapeutic Ratio

![Graphs showing therapeutic ratio for radiosensitive and radioresistant tissues.]

A) Radiosensitive (Favorable)
B) Radioresistant (Unfavorable)
Cell Survival Curves (Single Fx)
Survival Curve Multiple Fraction

- **Surviving Fraction**
- **Dose (Gy)**
- **Surviving Fraction vs. Dose (Gy)**
- **Survival Curve for Single Doses**
- **Effective Survival Curve for a Multi-Fraction Regimen**
- **D_{10} = 2.3 \times D_0**
- **Effective D_0**
- **Effective D_{10}**
Predicting Normal Tissue Reactions

- Dose
- Volume
- Fraction Size
- Elapsed Rx Time
How X-Rays Are Made

Example of a Hooded Anode therapy tube
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Therapeutic X-ray Production

• The forward traveling X-rays are first shaped by 2 sets of very thick tungsten collimators.

• The second set of mobile jaws establishes the size of the field projected and have a transmission factor of ~1%.
The Modern Linear Accelerator

- Accelerating tube
- Target
- Collimator
- Beam shutter
- Bending magnet
- Quadrupole focusing magnets
- Rotating seal carrying R.F.
- Wave guide carrying R.F.
- 270° bending magnet
- 90° bending magnet
- Wave guide
- R.F. power injected to give standing waves
- Inject
- Injected to turn around magnet
- R.F. power target
- Quadrupole focusing magnets
- Wave guide carrying R.F.
- Collimator
- Target
- Accelerating tube
- Beam shutter
Electron Beam

- The electron beam is created by removing the target from the path of the accelerated electrons.

- A scattering foil is used to “spread out” the very narrow electron stream.
Planning and Delivering Treatment

- Consultation
- Simulation
- Treatment Planning
- Verification & Treatment Delivery
Simulation (60-120 Minutes)

- Immobilization
- Field definition
- Obtain films of ports to be used
- CT scan if 3-D treatment planning
- Mark patient
- Obtain dosimetric information/ contour
Simulator
Immobilization
Field Definition
Treatment Planning (Minutes to Hours)

- Define the target volume
- Identify critical structures
- Design blocks
- Prescribe dose
- Plan beam arrangement and energies to best cover target and avoid critical structures
- Calculate dose
Treatment Planning
Designer Blocks
Verification & Delivery
(10 Minutes)

- Reproduce set up
- Verify treatment plan and parameters
- Obtain port films to document treatment area
- Deliver treatment
Verify Set Up
Deliver Treatment
Case: Esophageal Carcinoma

- 71 y.O. Male with 3 month hx of dysphagia. Evaluation with esophagoscopy, CT scan, barium swallow and esophageal ultrasound revealed a T3N1 adenocarcinoma of the esophagus.
- Plan: chemoradiation perhaps followed by surgery. Taxol/carboplatin/5fu + 50 Gy.
Esophageal Adenocarcinoma: Planning CT Scan
Esophageal Cancer: Dose Volume Histogram for Liver
Simulation Film for Esophageal Cancer
Port Film
Treatment of Esophageal Cancer
Case: Pituitary Macroadenoma

- Referred for definitive treatment of tumor, too large for complete surgical resection.
- Plan: 45 Gy to region over 5 weeks.
Pituitary Macroadenoma: Axial CT Scan
Pituitary Adenoma – 3 Field Technique
Pituitary Adenoma – 3 Field Technique
Case: Recurrent Oropharyngeal Cancer

- Now with recurrence on posterior pharyngeal wall, extensive.
- Plan: concurrent chemoradiation 40 Gy with 5FU and cisplatin.
Recurrent Oropharyngeal Cancer: Treatment With IMRT
Recurrent Oropharyngeal Cancer: Treatment With IMRT
Case: Prostate Cancer

• 63 y.O. Male with t1cn0m0 adenocarcinoma of the prostate, present in 1 of 6 cores, Gleason sum 5 (3+2) with presenting PSA of 4.3.

• Options of surgery and radiation discussed.

• Radiation options: EBRT, IMRT, brachytherapy.
IMRT Treatment Plan for Prostate Cancer
IMRT Treatment Plan for Prostate Cancer: Sagital Image
Statistics for IMRT Prostate Cancer Treatment Plan

### Desired Target Dose
Deliver 22 fractions over 22 days (inclusive)

<table>
<thead>
<tr>
<th>Minimum dose to</th>
<th>Seminal vesicles</th>
<th>26.00 Gy</th>
<th>1.18 Gy per fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum dose to</td>
<td>Prostate bed - target</td>
<td>44.00 Gy</td>
<td>2.00 Gy per fraction</td>
</tr>
</tbody>
</table>

Planning Parameters: Dr. Pollock: Male Prostate

### Total Delivered Dose
Deliver Prostate bed - target 44.00 Gy total 2.00 Gy per fraction

### Total Accumulated Dose
Deliver 44.00 Gy at 83.8% of maximum
(minimum dose to Prostate bed - target PTV, 32.83 Gy, is 62.5% of maximum)

<table>
<thead>
<tr>
<th>Target Name</th>
<th>Goal (Gy)</th>
<th>Vol Below Goal (%)</th>
<th>Min (Gy)</th>
<th>Max (Gy)</th>
<th>Mean (Gy)</th>
<th>S.D. (Gy)</th>
<th>Vol. (cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seminal vesicles -</td>
<td>26.00</td>
<td>0.00</td>
<td>27.84</td>
<td>51.99</td>
<td>37.42</td>
<td>7.51</td>
<td>14.82</td>
</tr>
<tr>
<td>Prostate bed - target</td>
<td>44.00</td>
<td>0.63</td>
<td>40.18</td>
<td>52.52</td>
<td>48.16</td>
<td>1.31</td>
<td>48.38</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Structure Name</th>
<th>Limit (Gy)</th>
<th>Vol Above Limit (%)</th>
<th>Min (Gy)</th>
<th>Max (Gy)</th>
<th>Mean (Gy)</th>
<th>S.D. (Gy)</th>
<th>Vol. (cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-target Tissue</td>
<td>48.00</td>
<td>0.31</td>
<td>33.45</td>
<td>52.26</td>
<td>6.74</td>
<td>8.60</td>
<td>*********</td>
</tr>
<tr>
<td>Tissue</td>
<td>48.00</td>
<td>0.59</td>
<td>63.44</td>
<td>52.52</td>
<td>6.95</td>
<td>9.09</td>
<td>*********</td>
</tr>
<tr>
<td>Bladder</td>
<td>29.00</td>
<td>37.77</td>
<td>73.31</td>
<td>51.99</td>
<td>25.40</td>
<td>12.50</td>
<td>194.10</td>
</tr>
<tr>
<td>Femoral Head (Lt)</td>
<td>10.00</td>
<td>7.89</td>
<td>4.40</td>
<td>2.63</td>
<td>13.92</td>
<td>7.21</td>
<td>1.89</td>
</tr>
<tr>
<td>Femoral Head (Rt)</td>
<td>10.00</td>
<td>8.75</td>
<td>4.54</td>
<td>2.88</td>
<td>13.13</td>
<td>7.50</td>
<td>1.88</td>
</tr>
<tr>
<td>Ant Rectum</td>
<td>46.00</td>
<td>3.41</td>
<td>2.06</td>
<td>2.36</td>
<td>49.63</td>
<td>28.51</td>
<td>12.87</td>
</tr>
<tr>
<td>Post. Rectum</td>
<td>30.00</td>
<td>14.29</td>
<td>8.82</td>
<td>1.84</td>
<td>38.86</td>
<td>18.78</td>
<td>9.54</td>
</tr>
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</table>
BAT Axial Image With Structures and Isodoses
BAT Sagital Image With Structures and Isodoses
BAT Sagital and Axial Images
Acquiring BAT Image
Treatment Head of IMRT
Small Adjustments to Table Position
Computer Program Drives Leaves
Why Not Use External Beam Alone?

- Using brachytherapy takes advantage of the inverse square law:
  \[ \text{Exposure} \sim \frac{1}{R^2} \]
- In this way, the therapeutic ratio is maximized by delivering high doses to the target tissue while respecting normal tissue tolerances
Brachytherapy Seed Implant for Prostate Cancer
Base of Tongue Implants
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7 Years Later
Effects of Radiation on Normal Tissues

- Acute: bone marrow, ovary, testis, salivary gland, small bowel, stomach, colon, oral mucosa, larynx, esophagus, skin, bladder, vagina
- Late: lung, liver, kidney, heart, spinal cord, brain, thyroid, lymph vessels, pituitary, breast, bone, cartilage, pancreas (endocrine)
Who Should Schedule a Rotation in Radiation Oncology?

Anyone considering one of the following specialties:

- ENT
- GYN (esp. Gyn Onc)
- General Surgery
- Thoracic Surgery

- Pediatric Oncology
- Hematology Oncology
- Urology
- Neurosurgery
Question #1

If given the job of loading 10 radioactive Ir-192 seeds into a tube, which would be better?

- Doing the job in 30 seconds at a distance of 1 foot
- or
- Doing the job in 60 seconds at a distance of 2 feet
Question #2

Clinical case: 57 y.o. male undergoes a low anterior resection of a T3 N1 rectal cancer. Margins of the resection were negative, but the tumor had gone through the bowel wall and 3 out of 18 lymph nodes were involved with cancer. A course of radiation therapy is recommended to treat the pelvic lymph node regions on the tumor bed.

Is this an example of **DEFINITIVE** or **ADJUVANT** treatment?
Question #3

Who gets more on the job exposure to ionizing radiation?

Radiation Oncologist
Cardiologist
Urologist