Conflict of Interest Disclosure

• None
Learning Outcomes

• Be aware of the basic principles of radiation therapy.
• Describe, in basic terms, the process for planning and delivering radiation therapy.
• Outline the role of radiation in treating common malignancies for cure and palliation.
• Describe how radiation therapy is used for pain control in cancer.
• Describe the common side effects of radiation therapy and approach to their management.
• Be familiar with the use of radiation therapy in the treatment of oncologic emergencies.
At least 50% of people with cancer may benefit from a course of radiotherapy (RT)

Treatment goals:

1. curative (~50%)
2. palliative
   » Lower, more concentrated dose-fractionation schedules; improve QOL while minimizing side-effects
3. maximize local control
4. prolong survival
Radiation Therapy Overview

RT can be the primary modality or used in combination with other cancer therapies:

- Radiation Oncologist
- Surgical Oncologist
- Medical oncologist

Specific management is evidence-based and individualized, accounting for various factors…

…disease site and stage …patient factors
Principles of Radiation Therapy: What Radiation is Used?

The Electromagnetic Spectrum

- Radio Waves
- TV Waves
- Microwave
- Infrared
- Visible Light
- UV (Tanning Booth)
- Medical X-Rays (Gamma Rays)

Increasing Frequency, Decreasing Wavelength

- Thermal
- Optical
- Broken Bonds (Damages DNA)

Non-Ionizing

Ionizing

100 KV…6 MV…..18MV

RT Beam Energies
## What Radiation is Used?

<table>
<thead>
<tr>
<th>Radiation Beam Energy</th>
<th>Effective Treatment Depth</th>
<th>Clinical Examples</th>
</tr>
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<tbody>
<tr>
<td>100-250KV</td>
<td>Millimeters</td>
<td>Basal/ Squamous cell skin cancer</td>
</tr>
<tr>
<td>4-10 MV</td>
<td>Few centimeters</td>
<td>Head / Neck cancer; lung cancer</td>
</tr>
<tr>
<td>18-25 MV</td>
<td>Several centimeters</td>
<td>Prostate / Cervical cancer</td>
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Beam energy choice is based on location/depth of cancer and NOT on intensity of treatment
## What Radiation is Used?

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Beam energy choice is based on location/depth of cancer and NOT on intensity of treatment.
How is the Radiation Delivered?

Externally = Teletherapy = **External Beam RT**
- radiation is at a distance to cancer
- modern Linear Accelerators (LINAC) produce Gamma rays from electricity
  (Old=Cobalt machines, Co-60)

Internally = **Brachytherapy**
(radiation is placed close to cancer)

Systemic (Unsealed) **Radioisotope Therapy**
(radiation given in pill or IV liquid form)
Ingested Radiopharmaceuticals

- $^{131}$I thyroid remnant ablation, after near-total thyroidectomy for differentiated thyroid cancer (DTC) = Pap + Foll (not Med / Anapl)
  - 50 – 80% of tumors will concentrate iodine
  - $t_{1/2} = 8$ days; very low energy emitter of gamma rays and electrons; damages cell and nearby cells; little escapes the body; kept in isolation
  - given orally as inpatient (doses > 1 GBq or 30mCi)
  - Prep:
    - increase TSH with thyrotropin alfa (Thyrogen) injections or THW (off T4 x 4 wks)
    - Low Iodine Diet x 2 wks
  - Can reduce recurrence rates, improve survival, allow follow up whole body I – 131 scan (WBS) and sensitive thyroglobulin measurements, and palliate metastatic DTC
  - Comprehensive reference: 2015 American Thyroid Association Mx Guidelines for Thyroid Nodules and Differentiated Thyroid Cancer

http://www.thyroid.org/professionals/ata-professional-guidelines/
How is the Radiation Delivered?

Teletherapy = External Beam RT = EBRT

is most common form
EBRT Techniques

External beam RT machines (linear accelerators) produce various beam energies (4 MV, 6MV, 18MV)

Beam energy choice is based on location/depth of cancer and NOT on intensity of treatment
EBRT Techniques

Conventional External Beam Radiotherapy

Stereotactic Radiation Therapy/ Radiosurgery

Intensity-modulated Radiotherapy (IMRT)

Image-guided Radiotherapy (IGRT)
Radiation Dose

Describes treatment intensity

Unit of RT dose: Gray (Gy)

Old unit “rad” is replaced by “centigray”

(1 centigray = 1 rad)
Dose Fractionation

Division of total prescribed dose allows cancer cell killing while minimizing normal cell damage (facilitates recovery of normal tissue)
Dose Fractionation

**Standard Fractionation RT**
(70 Gy/35f/7wks; 2 Gy/d, M-F)
week: 1 2 3 4 5 6 7

Microscopic 50 Gy/ 25f  Gross 70 Gy/35f

**Accelerated Fractionation RT**
eg. DAHANCA (Danish) protocol
(70 Gy/35f/6wks; 2 Gy/d, M-Th + 2Gy BID on F)
week: 1 2 3 4 5 6

Microscopic 50 Gy/ 25f  Gross 70 Gy/ 35f
How does the Radiation Work?

DNA is the critical target for radiation.

RT produces breaks in the DNA through ionization and the production of free radicals, enhanced by the presence of oxygen.

The damage caused by radiation can cause cell death or loss of ability to repeatedly reproduce.
How does the Radiation Work?

Irradiated cancer cells may die immediately, within hours, days or weeks.

Therefore, maximal response will usually not be immediate.

The full effects of RT depend not only on total dose but also on dose per fraction, total treatment time, and delivery schedule.
RT Principles Radiobiology

- **4 R’s of Radiobiology**
  - Repair
  - Repopulation
  - Reoxygenation
  - Redistribution

- **Fractionation:**

  - division of total prescribed dose and given in a series of fractions separated in time
Therapeutic Ratio

\[ TR = \frac{\text{Tumour Control Probability}}{\text{Normal Tissue Complication Probability}} \]
RT Principles: Radiobiology - R’s that spare normal tissues

• Repair
  – Of radiation damage
    • Types of damage:
      – Base pair damage
      – DNA-protein crosslinks
      – Single DNA strand breaks
      – Double DNA strand breaks
    • 200 – 300 genes responsible for DNA repair
    • The degree of repair is intrinsic to the tumor type and/or normal tissue type
      – Occurs more in normal tissues than in tumor so Fractionation allows normal tissues to recover preferentially

• Repopulation
  – Allows normal tissues to recover (skin, mucosa)
    – if RT is too prolonged by Fractionation, tumor can divide also
    – “accelerated repopulation”: occurs when treatment with a cytotoxic agent causes an increase in tumor cell division rates
RT Principles:
Radiobiology- R’s that enhance tumour cell kill

- Reoxygenation
  - Hypoxia induces increased radiation resistance
  - If RT is given Fractionated, then hypoxic cells can reoxygenate and their presence does not significantly affect tumour response
RT Principles: Radiobiology - R’s that **enhance** tumour cell kill

- **Redistribution**
  - Most radio-sensitive is G2- M phase,
  - Most radio-resistant is late S

- If RT is given **fractionated**, then radio-resistant late S cells can redistribute into other more radio-sensitive with less affect tumour response

---

Cell Cycle
RT Principles: Radiobiology Summary

- **4 R’s of Radiobiology**
  - Reoxygenation
  - Redistribution
  - Repair
  - Repopulation

- **Fractionation:**
  - Division of total prescribed dose and given in a series of fractions separated in time
  - Allows increased cancer cell kill (reoxygenation & redistribution) while minimizing normal cell damage (repair and repopulation)
Planning & Delivery of Radiation Therapy

Referral
Radiation Oncologist Consultation
Pre-radiation Assessment
Simulation
Treatment Planning
Calculation and Data Entry
Radiation Treatment Delivery
Planning & Delivery of Radiation Therapy

**Prioritization Guidelines**

- **Emergent:** Treat within 48 hours
- **Urgent:** Treat within 7 days
- **Intermediate:** Treat within 14 days
- **Standard:** Treat within 21 days
- **Other:** Individualized target dates

---

**Diagram:**

1. **Referral to Radiation Oncologist** ~ 2 weeks
2. **Radiation Oncologist Consultation**
   - **Decision made to treat with radiation** ~ 2 weeks
3. **Prioritization by Radiation Oncologist**
   - **(Pre-radiation Assessments if indicated)**
4. **Simulation** ~ 2-4 weeks
5. **Treatment Planning**
6. **Calculation and Data Entry**
7. **Radiation Treatment Delivery**
Pre-radiation Assessments

- Staging investigations
- Pulmonary function tests
- Dental consultation
- Nutritional consultation
- Cardiology Pacemaker evaluation
- Cancer Site Team case discussion
Simulation

Immobilization devices

With the use of a radiotherapy (dedicated CT scan) simulator, the patient is placed in the treatment position and the areas of interest are imaged.

Reference ‘markings’ or tattoos are placed on the skin.
Treatment Planning, Calculation & Data Entry

Target volumes and normal tissues carefully outlined

Beam energies & arrangements determined

Dose calculations and data entry

Plan is finalized and approved for treatment
Radiation Treatment Delivery

IMRT for head and neck cancer
Radiation Treatment Delivery

Stereotactic radiosurgery (SRS) for a brain met
Radiation Treatment Delivery

New technology: multileaf collimator (MLC) which defined conformal beam aperture

Custom-made lead-alloy (cerrobend) shielding defined beam shapes
**IMRT** = Intensity Modulated Radiation Therapy

**VMAT** = Volume Modulated Arc Therapy

https://www.youtube.com/watch?v=GYqNcuXN-hQ
Radiation Treatment Delivery
# Common Treatment Protocols for Cure

<table>
<thead>
<tr>
<th>Tumor Type</th>
<th>Treatment Protocol</th>
<th>Dose Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUNG Ca Inoperable</td>
<td>C + R</td>
<td>6000 cGy / 30f / 6 weeks</td>
</tr>
<tr>
<td>BREAST Ca</td>
<td>S +/- C, then R</td>
<td>5000 cGy / 25f / 5 weeks</td>
</tr>
<tr>
<td>PROSTATE Ca</td>
<td>S or R+/− Hormones</td>
<td>7200 cGy / 36f / 7.5 weeks</td>
</tr>
<tr>
<td>COLORECTAL Ca</td>
<td>S, then C + R</td>
<td>5400 cGy / 28f / 5.5 weeks</td>
</tr>
<tr>
<td>HEAD &amp; NECK Ca</td>
<td>Early: S or R, Adv: S and C + R or C + R</td>
<td>7000 cGy / 35f / 7 weeks</td>
</tr>
</tbody>
</table>

Ca = Cancer, S = Surgery, C = Chemotherapy, R = Radiotherapy

*NSCLC = Non-small cell lung cancer, +SCLC = Small cell lung cancer
## Common Treatment Protocols for Palliation

### Examples of Areas Treated:
- **Chest**: single fraction
  - 1 week
  - 2 weeks
- **Bone**: single fraction
  - 1 week
- **Brain**: 1 week
  - 2 weeks
- **Head & Neck**: 2-6 weeks

<table>
<thead>
<tr>
<th>Radiation Dose</th>
<th>Fractionation</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 cGy</td>
<td>1f / single</td>
<td></td>
</tr>
<tr>
<td>2000 cGy</td>
<td>5f / 1 week</td>
<td></td>
</tr>
<tr>
<td>3000 cGy</td>
<td>10f / 2 weeks</td>
<td></td>
</tr>
<tr>
<td>7000 cGy</td>
<td>35f / 6-7 weeks</td>
<td></td>
</tr>
<tr>
<td>2400 cGy</td>
<td>3f / Day 0, 7, 21</td>
<td></td>
</tr>
</tbody>
</table>
Use of Radiation Therapy for Pain Control
Use of Radiation Therapy for Pain Control

• Palliation of local tumour progression, neuropathy
Side Effects of RT

Side effects are the result of damage to normal healthy tissue

Depend on the site of the body being treated – usually localized

Potential side effects are explained to patient and family prior to initiating treatment
Side Effects of RT

Site-specific

Radiosensitivity of the tissue

Dose of radiation and fractionation schedule

Size / volume of the treatment field

Other: comorbidities, age, nutritional status, combination with surgery / chemotherapy

Retreatment to same area has higher risk of permanent side effects and may be less effective
# Side Effects of RT

## Normal Tissue Tolerance

<table>
<thead>
<tr>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testes</td>
<td>Liver</td>
<td>Mucosa</td>
</tr>
<tr>
<td>Ovary</td>
<td>Skin</td>
<td>Adult Brain</td>
</tr>
<tr>
<td>Eye (lens)</td>
<td>Bone</td>
<td>Bone</td>
</tr>
<tr>
<td>Kidney</td>
<td>Bone Marrow</td>
<td>Cartilage</td>
</tr>
<tr>
<td>Lung</td>
<td>Spinal Cord</td>
<td>Muscle</td>
</tr>
<tr>
<td></td>
<td>Bowel</td>
<td>Rectum</td>
</tr>
</tbody>
</table>
Acute Side Effects

Occur during and up to six weeks following radiation therapy

Generally resolve within 4-6 weeks after treatment completes

Due to the effect of radiation on rapidly dividing cells in the treatment field
Late Side Effects

Occur months to years following radiation therapy

Tend to be permanent

Usually the result of damage to microcirculation
Common Acute Side Effects and Management

Fatigue
Nausea
Skin reactions/alopecia
Acute mucosal reactions
Xerostomia
Diarrhea
Pneumonitis
L’Hermittes Syndrome
Fatigue Management

Validation & education of patient and family

Activity planning and energy conservation

Try to maintain regular sleep hours

Reduce stress and anxiety (counseling & support)

Good nutrition and fluid intake

Treat underlying cause, if identified
Radiation-Related Nausea Management

Pre-treatment anti-emetics

Zofran, Maxeran, Stemetil, Gravol
as needed

Dexemethasone may be helpful

Dietitian consultation
Skin Reaction

Most common side effect of external beam radiation therapy

Begins ~ 2 weeks into treatment

Peaks ~ 2 weeks after treatment

Resolves over 3-6 weeks after radiation therapy has finished
Acute Skin Reactions

Radiation skin reaction: erythema and early dry desquamation
Acute Skin Reactions: General Advice

Bathe or shower using luke warm water and mild soap

Use an electric razor

Avoid commercial creams in treatment area

Sun protection of the area during and after treatment

No sunscreen during and until reaction has resolved
# Acute Skin Reactions: Management

<table>
<thead>
<tr>
<th>Acute Skin Reactions</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little to no changes</td>
<td>Dry dusting of cornstarch or cornstarch baby powder</td>
</tr>
<tr>
<td>Slight erythema</td>
<td>Alcohol-free Aloe Vera</td>
</tr>
<tr>
<td>Mild dryness/itch</td>
<td></td>
</tr>
<tr>
<td>Dry peel/ increased itchiness</td>
<td>1% Hydrocortisone cream</td>
</tr>
<tr>
<td>Moist peel/ tenderness</td>
<td>Flamazine or Tegagel</td>
</tr>
<tr>
<td></td>
<td>Saline soaks/sitz baths</td>
</tr>
<tr>
<td></td>
<td>Tylenol</td>
</tr>
</tbody>
</table>
Acute Mucosal Reactions

Radiation mucositis: early erythema of soft palate
Acute Mucosal Reactions: General Advice

Good oral hygiene

Baking soda /salt water rinses

Nutritional/dietary counseling

Avoid alcohol/smoking
Acute Mucosal Reactions: Management

Moderate to severe oral mucositis/Esophagitis

Oncology Mouthwash (Maalox® / Lidocaine) (swish and swallow before meals)

Anelgesics (Codeine elixir)

Admission for IV/parenteral nutrition, G-tube
Acute Mucosal Reactions: Management

*Candida infection*

Nystatin 500,000 units po QID for 7 days

*swish and swallow*

Canesten lozenges

(dissolved QID)
Xerostomia: Management

*partial, permanent…some recovery even 1-2 years later*

- Regular dental assessments and cleaning
- Good oral hygiene
- Artificial saliva products trial
- Oral pilocarpine trial may stimulate residual gland function
Diarrhea: Management

- Small frequent meals
- Increase fluid intake
- Low fibre/fat diet
- Avoid gas causing food and caffeine
- Imodium
Side Effects in Special Tissues: Lung

**Pneumonitis Management:**

- 6-12 weeks post RT to chest; dry cough, SOBOE, pleuritic pain; early in-field changes on CXR

Prednisone 30-40 mgs daily-tapered over 6-8 weeks

Oxygen & Inhalers prn

Most resolve***Can be Life Threatening***

Re-refer to Rad. Oncologist if suspected
Side Effects in Special Tissues: Spinal Cord

L’Hermitte’s Syndrome Management:

- Transient demyelination, 6-12 months post-RT to spine, shock-like in arms / legs with neck flexion, full recovery expected

Non-steroidal anti-inflammatories

Avoid neck flexion
Emergency Situations in Radiation Oncology

Spinal Cord Compression (SCC)

Superior Vena Cava Obstruction (SVCO)
Spinal Cord Compression (SCC)

Occurs when a tumour compresses or invades the spinal cord

Most commonly due to metastases to vertebral body (C)

Timely diagnosis and intervention has critical impact on prognosis
SCC Symptoms

- Back Pain (+ cancer patient = r/o early SCC)
- Leg weakness
- Numbness
- Stool and/or urinary incontinence (late)
- Irreversible Paraplegia (very late)

Timely diagnosis and intervention has critical impact on outcome

Weeks / Days: 90% pain, 80% weakness, 50% sensory loss, 50% autonomic dysfunction

Hours: 15 - 45% irreversible paraplegia
SCC Signs

- Bilateral leg weakness
- Sensory dermatomal level
- Hyperactive or absent reflexes
- Poor anal sphincter tone

T4: nipple  T10: umbilicus
- AP spine Xray
  - Loss of height of VB
  - “winking owl sign” = disappearance of pedicle on AP view
Most important: MRI entire spine
- noninvasive
- multiple levels visualized
- neurological details

Metastatic lung ca to spine causing spinal cord compression at T9 vertebral body
SCC Management

Timely diagnosis and intervention has critical impact on outcomes
SCC Management

• Surgery (<24 hrs)
SCC Management

- Radiotherapy(<24 hrs)

  800 cGy / 1 #
  (single)

  2000 cGy / 5 #
  (1 week)

  3000 cGy / 10 #
  (2 weeks)
Prognosis for SCC treated with RT*
(Byrne et al. NEJM. 1992.)

Status at Start of RT | % Ambulatory post-RT
-----------------------|------------------------
ambulatory             | > 80%                  
paraparetic            | ~ 50%                  
paraplegic             | < 10%                  

2005: RCT using decompressive surgical resection
(Patchell et al. Lancet. 2005)

<table>
<thead>
<tr>
<th>Surgery + RT*</th>
<th>vs</th>
<th>RT* alone</th>
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<tr>
<td>walking post-Rx</td>
<td>84%</td>
<td>54%</td>
</tr>
<tr>
<td>Not walking to walking</td>
<td>69%</td>
<td>19%</td>
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Also longer duration of walking, less need for steroids and opioids, increased survival with surgery.
Spinal Cord Compression (SCC)

- Any person with a cancer diagnosis complaining of back pain – must rule out SCC
- Diagnosis should be confirmed with MRI
- Begin steroids & immediately contact radiation oncologist / neurosurgeon to discuss
- Steroids (dexamethasone 10 mg then 4 mg po/iv qid)
- Management with surgery and/or radiation therapy must be instituted within hours of onset of the neurological symptoms for any chance of recovery
Patient Education for SCC

At risk patients should be taught to report any back pain, numbness/tingling in arms or legs, or muscle weakness.

Superior Vena Cava Obstruction (SVCO)

Obstruction of blood flow through the superior vena cava

Caused by:
- Tumour
- Enlarged lymph nodes
- Thrombosis
Superior Vena Cava Obstruction (SVCO)

- Any person with a malignancy in the chest (usually lung cancer) with:
  - Dyspnea
  - Swelling of face and upper torso
  - Venous distension in chest and neck
SVCO Symptoms & Signs

Dyspnea

Swelling of the face and upper torso

Distention of veins in neck, chest, upper back and arms

Nonproductive cough
SVCO Symptoms & Signs
SVCO Investigations

• CT chest with contrast
SVCO Management

• If suspected, contact radiation or medical oncologist to discuss immediately
• Diagnosis confirmed clinically
• Supportive measures
  – Bed rest, with head elevated
  – Oxygen
  – Remove restrictive clothing
  – Avoid IV placement in affected arms
• SVCO requires *urgent* treatment
  – Steroids (dexamethasone 10 mg then 4 mg po/iv qid)
  – RT or Chemo after histology obtained
  – stent
SVC Stent
SVCO Outcome

Prognosis depends on the underlying disease
Radiation Oncology Basics

Key Messages

- RT: noninvasive, effective cancer therapy used alone or with surgery & chemotherapy with goals for cure and palliation (local control, improve survival)
- Process for RT planning and delivery: a team of health care professionals and can require days to weeks
- Cancer pain is effectively relieved by RT with few side effects
- Common acute side-effects of RT mostly resolve and can be managed to complete the RT as planned
- Emergencies such as SCC and SVCO need to be recognized, referred, and managed early
Radiation Oncology Basics