Role of the Physicist in Medicine

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• This pt presented with a lung cancer
• Left image displays a very good contrast-distinguish tissue layers
• Right image shows the localization image for patient position. Bony structure is not sharp.
• differ contrast-different energy
• 120KV (Left) vs. 6MV (Right)
• The reason is the different interaction in terms of the atomic number as well as the incident energy
• the probability of PE-\((Z/E)^3\) - that is why the bone image shows significant photon absorption.
• the probability of CS-\((1/E)\) – the amount of energy absorption is approximately the same for tissue or bone
• PE is dominant in diagnostic radiology while CS is in radiation therapy.
Outlines of the talk

- Introduction of medical physics
- Subfields of Medical Physics
- Beginning of Medical Physics
- Functions in medical physics
- External Radiation Therapy
- BrachyTherapy (Prostate Seed Implants)
- Educational Opportunity
What is a Medical Physicist?

A medical physicist is a professional who specializes in the application of the concepts and methods of physics to the diagnosis and treatment of human disease.
The Medical Physicist Bridges Physics and Medicine

Medical Physicist

Physics  Medicine

• To treat patients in medical field, the technologies are getting complex, therefore someone who can interpret this complexity is needed.
Where Did Medical Physics Begin?

On 8 Nov 1895, Wilhelm Conrad Röntgen (accidentally) discovered an image cast from his cathode ray generator.

-Unit: $1R = 2.58 \times 10^{-4} \text{ C/Kg}$
Henri Antoine Becquerel (1852-1908)

Discovery of Spontaneous Radioactivity (1896)
by uranium (natural material)
-1903 Nobel Prize with Curie
-Unit: $1\text{Bq}=1\text{disintegration per second (dps)}$

Marie Curie (1867 - 1934)

Isolation of Polonium and Radium
-1903 Nobel Prize with Becquerel
-1911 Nobel Prize
-Unit: $1\text{Ci}=3.7\times10^{10} \text{Bq}$
Functions In Medical Physics

• Clinical Medical Physics
  → Dosimetry, radiation safety, quality assurance, etc.

• Research and Development
  → Develop new therapeutic equipment or procedures, etc.

• Education
  → Training of medical physicists, physicians, technologists, radiation therapists, and medical dosimetrists.
What is the Medical Physicist’s Primary Discipline?

- 76% Radiation Therapy
- 15% Imaging Physics
- 4% Nuclear Medicine
- 3% Health Physics
- 1% Health Physics
- 1% Engineering
- 1% Administration

Source: AAPM Survey
Radiation Therapy

• Use of radiation to treat disease
  - primarily used to treat cancer
  - primarily using ionizing radiation
    • x-rays, high energy particles
      (Proton Therapy)
  - other modalities
    • Hyperthermia use heat-microwave
      and ultrasonic
    • Phototherapy utilize visible light
Why Radiation Therapy for Cancer?

- Cancer is uncontrolled cell growth
- Fatal in 50% of cases
- Side effects and dangers of RT
  - Normal tissues damaged also
  - DNA damage from ionizing radiation can cause cancer, mutations in later generations, malformations in developing embryos/fetuses
- Best to restrict RT to patients that already have a life-threatening disease
Radiation Therapy Fundamentals

- **Therapeutic dose to tumor**
  - 50 - 70 Gy ($1 \text{ Gy} = \text{J/kg}$)
- **Diagnostic dose**
  - 1 - 40 mGy
- **Normal background dose**
  - 1 mGy/year
Treatment Types

- EXTERNAL THERAPY
  - Medical Linear Accelerator (LINAC)
  - 4-20MV for X-ray & 6-20MeV for Electrons

- BRACHYTHERAPY
  - Radioactivity: I-125 & Ir-192
EXTERNAL THERAPY (LINAC)

Source: VARIAN co.
Treatment Unit
External Beam Radiotherapy

1: CT scanning
2: Tumour localisation
3: Skin reference marks
4: Treatment planning
5: Virtual simulation
6: Radiotherapy treatment
Therapy Responsibilities

• Planning of patient procedures

Contributed By: Dong (MD Anderson)
Treatment Planning

• TP is done by dosimetrist
• Tumor and organs contouring based on CT and MRI&PET Fusion
• Treatment Options: 2D, 3D, IMRT, RapidArc
• Total dose and daily dose with Fractions
• Beam selection by energy and pt thickness because of beam penetration
• Field Size and using aid devises (Wedge…)
• Check Dose Distributions of tumor and organs
• Independent double check with physicist/Program
Imaging in Radiation Therapy

- Tumor localization is important to give higher dose to the target
- Research and development in radiation therapy often involves using imaging to better locate the target
- Example: fusing CT and MR images or PET image
MRI/CT image fusion
3D calculation and evaluation

Mayo Clinic - Scottsdale
Dealing with moving targets

- Limitations of giving higher dose and smaller clinical margin (respiratory motion & cardiac motion)
- There are two approaches (tracking tumor motions & controlling respiratory motion)
What do therapy physicists care about?

• Accuracy of dose delivery
  - targeting accuracy
  - dose calculations
• Dose measurements
What to all medical physicists care about?

- Responsibility for all aspects of QA
  - performing machines calibration and QA
  - Chart review
  - Dose verification before treating pts
  - Brachytherapy planning and treatment
  - Maintaining ACR/State inspections
  - Radiation Safety Officer
What to all medical physicists care about?

- For the management
  - Oversee the work of physicists/dosimetrists
  - Staff evaluation
  - Staff Training for new technology and Physics
  - Budget planning
  - Recommend equipments
Quality Assurance Procedures

from the patient plan to the phantom plan
2. Setup Phantom with films and Ion Chamber

Place EDR2 films in the interesting area

Place Ion Chamber at ISO
Horizontal Plots

From phantom study

From Treatment Planing

Difference between the Planing and Measurement
Independent MU calculation for a secondary MU check
New development: RapidAcr therapy

- Precise, Fast, and Simple
- Maximize dose, accuracy, and the efficiency
- Varies Gantry rotate speed, dynamic MLC, and dose delivery rate
- Change the beam shape during each irradiation so that summed dose has desired shape
- Can “wrap” dose around critical normal structures
RapidArc Plan and MLC motion

1 MLC shape

Middle of MLC

End of MLC
Patient Positioning using kV-kV
Patient Positioning using CBCT
Real Time-RapidArc Treatment

Source: VARIAN co.
BrachyTherapy
Prostate Volume Study

The size of prostate (52mm) sagital Image

urethral
The shape of a central transverse image
Source: NY Times.
Completion
The physicist, who assesses seed placements and radiation doses, notes the exact location of each seed. Software is used to estimate dosages based on location of the seeds. If the placements and dosages are judged to be correct, the procedure is considered complete.
Quality Assurance

The delivered seeds are assayed by radiation oncology staff to make sure their accuracy. The deviation of seeds should be satisfied with a clinical error.

Well chamber for seeds QA

Electrometer to measure radiation from seeds
Preparing Implant

- Seed handling tools
- Glass for preventing the electrons
- Personal radiation film and ring badge
Radiation Survey

After the prostate implant, the operation room is surveyed by a G-M counter to find lost seeds.
After re-CT scan, a POSTPLAN is created by the radiation oncology staff. The dose distribution after the implant is compared with the PREPLAN.
Further Information of Medical Physics

• MP is well-known to undergrads
• Check out this opportunity for an fellowship
  http://www.aapm.org/education/
  GrantsFellowships.asp
• To be a qualified medical Physicist
  www.theabr.org
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