Patient Dose Outside the Treatment Field

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Outline

• Peripheral dose basics
• Peripheral dose from conventional linear accelerators
• Estimate of radiation effect for select beams
• Case study (given time): Consideration of treatment of L5 vertebrae in pregnant patient

Low Dose Effects

• Patient: cancer
  – Photons: Risk of death from cancer of 4%/Gy
  – Neutrons: quality factor roughly 30 for low dose
• Fetus: depends on gestation stage
  – Lethality, malformations, mental retardation, growth retardation, carcinogenicity, sterility and genetic abnormalities
  – Keep dose below 0.1 Gy

Peripheral dose basics

• Peripheral dose: Dose well outside the penumbra of the treatment fields

Peripheral dose depends on:
• Target dose, D
• Volume of peripheral region
• Particle type (photons, electrons) and energy
• Beam delivery system (accelerator, collimators, beam modifiers)
• Shielding

Energy, \( E = \text{dose} \times \text{density} \times \text{volume} \)
Measurement

- PTW TK-30 2 cm diameter ionization chamber
- Roos parallel-plate chamber
- IBA CC13 ionization chamber

Monte Carlo simulation

- Intricate geometries
- Exquisite detail in calculated quantities
- High accuracy, rivaling measurement
- Procedure: Validate Monte Carlo simulation with accurate measurement in simplified, representative geometry. Calculate peripheral dose in any geometry, including shielding and patient.

Dose $\Phi(E, x, \theta, L)$

Monte Carlo simulation is indispensable in radiotherapy

X-ray scatter and leakage

- Secondary particles: 75% neutrons, rest protons, alpha-particles: Siemens 18 MV 0.7% equivalent dose (Sv/Gy), Varian 15 MV 1.5%, 18 MV 3% (Chibani and Ma, 2003)
- Fetal shields can reduce dose to the fetus by 50%

Testicular Shield

- Clamshell shield
- Water-filled cylinder
- Plastic Water

Leakage negligible (measured with jaw closed)
Point A dose, partially shielded - MC: 1.2-1.6%, CC13: 1.5-1.8%
Point B dose, fully shielded - MC: 0.2-0.4%, CC13: 0.5-0.9%, TLD: 0.6%
TLD's on patient 2-3 time higher dose since field edge closer to testicles.
Monte Carlo simulation

Source of peripheral dose: Electrons

- Leakage is negligible
- Scattered electrons
- Secondary particles
  - Bremsstrahlung

Applicator leakage

Film wrapped around applicator

Applicator Simulation
Applicator retrofit to reduce leakage

Rough Estimate of Radiation Effect

- Risk of death from cancer from peripheral dose is approximately 4%/Sv to the whole body
- X-rays – 18 MV
  - Phantom scatter 3%, rapid drop with distance [0.6%]*
  - Collimator scatter 1%, rapid drop with distance [0.2%]*
  - Leakage < 0.1% everywhere [0.3%]*
  - Secondary particles (neutrons) 3% (Sv/Gy) [2%]**
- Electron peripheral dose – 21 MeV: collimator scatter
  - Electrons 3%, superficial, drops with distance [0.2%]*
  - Bremsstrahlung 2%, very rapid drop with distance [0.2%]*

* Rough estimate of risk of death: 70 Gy, 5' tall patient, 10x10 field, **From Chibani and Ma, 2003

Bibliography

- D. Sawkey and B. Faddegon, "Monte Carlo simulation of linear accelerator treatment head and patient

