Outline
A. Requirements and paradigms for beam commissioning
B. Types of commissioning measurements
C. Issues associated with commissioning measurements
Indrin J. Chetty, AAPM 2006 Monte Carlo CE course
Large field E’ beam simulation using BEAMnrc/EGSnrc

Asymmetric Effects: Beam Angle of 0.9°

Beam modifiers: MLC transport models: Leaf leakage

Tongue-and-groove effect maximized:
Delivered with even/odd leaves closed half the time, resp.

DYNVMLC CM in BEAMnrc (120 Leaf MLC)

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Beam model verification: 120 leaf MLC

For beam models based on PS calculations, treatment head geometric details are critical!

15 MV, 10x10 profile in water at 10 cm

FF w/ Cu design

FF w/ Tungsten

Solid Line = Measurement

From AAPM Tg-105: Chetty et al. Med Phys 2007

Electron Beams: Multiple Source Models

Experimental Verification: Radiation Transport

Radiation transport accuracy: test the accuracy under circumstances in which the MC algorithm is likely to provide most benefit - small field sizes, non-equilibrium conditions, heterogeneous media.

Loss of Charged Particle Equilibrium (CPE)

CPE exists in a volume if each charged particle (electron) leaving the volume is replaced by an identical electron entering the volume.

In narrow field, CPE is lost and dose reduction can be severe.

Lateral Scattering of electrons: Monte Carlo simulation, 10 MV pencil beam
Small field central axis depth dose: slab phantom

*Build down effect* – severe dose reduction caused by scattering of electrons into the lung tissue. Dose builds up in the tumor resulting in underdosage at tumor periphery.

Implications for “island” tumors

“Ring” of underdosage gets larger for smaller tumors (as the tumor size approaches the electron range)

Ion chamber measurements: 2x2, 6x, 2x2 cm

The Energy Effect

“Ring” of underdosage gets larger with beam energy due to the increased electron range.

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Issues with measurements – small field sizes


Measurements with small field sizes in low density tissues are even more complicated – $\varepsilon'$ range increases and $\varepsilon'$ equilibrium is lost at larger field sizes.


AAPM TG No. 155 Small Fields and Non-Equilibrium Condition Photon Beam Dosimetry: Das and Francescon et al.

Experimental Verification: “heterogeneous” phantoms

Aarup et al, Radiotherapy & Oncology 2009

Lung

$\rho_{\text{lung}} = 0.4 \text{ g/cc (Expiration)}$

$\rho_{\text{lung}} = 0.1 \text{ g/cc (Deep Inspiration)}$

$\rho_{\text{lung}} = 0.1 \text{ g/cc}$
Slab phantoms with heterogeneities: depth doses

Slab phantoms with high density materials

Verification for electron beams

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9 MeV electrons – effect of voxel size

MeV electrons – effect of voxel size and smoothing

Anthropomorphic phantoms
Summary

Commissioning of beam models must include measurements to verify the accuracy of the head model, as well as the radiation transport model in the patient. Measurements in complex geometries, small fields and non-equilibrium conditions, will be helpful to verify the expected improved accuracy of the MC algorithm under such circumstances. Measurements in complex geometries is difficult and must be done with care, to minimize systematic errors. When performing direct treatment head simulation, accurate geometric details of the components are critical!

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