Monte Carlo - II: Clinical impact
Monte Carlo for Electron Beam Treatment Planning

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Outline

- Current status of electron Monte Carlo
- Implementation of Monte Carlo for electron beam treatment planning dose calculations
- Application of Monte Carlo in conventional and modulated electron beam therapy
- Monte Carlo for other beam modalities

Why Use Monte Carlo for Radiotherapy Treatment Planning

An accuracy of about 5% in dose delivery is required to effectively treat certain types of cancers and to reduce complications.

ICRU Reports 24 (1976) and 42 (1988)

The Accuracy Requirement for Treatment Planning Dose Calculation

$$\sigma^2=\sigma^2_{calib}+\sigma^2_{dose}+\sigma^2_{setup}+\sigma^2_{motion}+\ldots$$

and

$$\sigma \geq 2\sigma_{dose}=5\%$$

then

$$\sigma_{dose}=2.5\%$$

Uncertainties in Electron Beam Dosimetry

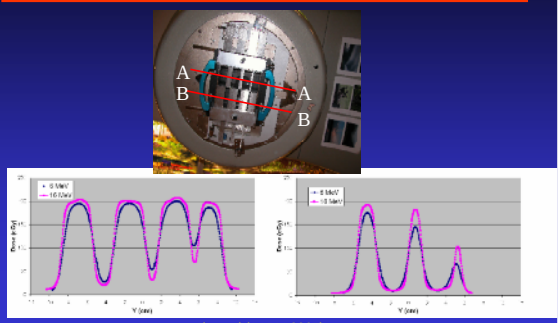
Limitations of dose calculation algorithms

- source models
- Beam modifier effect
- heterogeneous patient anatomy

Limitations of dose measurement systems

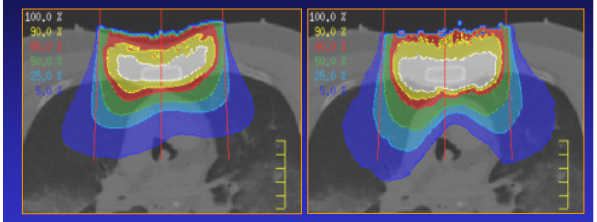
- non-calibration conditions
- complex beam modifier geometry

Fluence Profiles from an eMLC



Jin et al (AAPM 2007)

Pencil Beam Pinnacle[3] Monte Carlo (BEAM)



Achterberg et al (ESTRO 1999)

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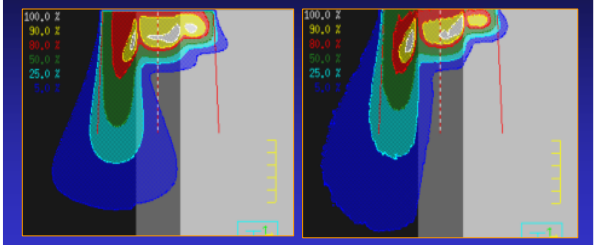
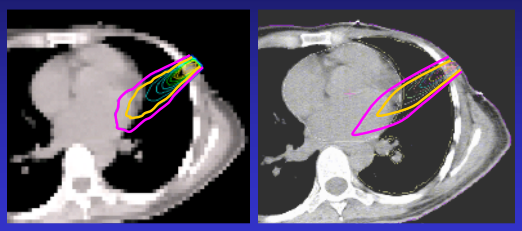


Achterberg et al (ESTRO 1999)

20 MeV Beamlet Distributions

Monte Carlo (MCDOSE) Pencil Beam (FOCUS)



Ma et al (PMB 2000)

Monte Carlo Codes for Electron Beam Dose Calculations

- The BEAMnrc/DOSXYZnrc system
- Voxel Monte Carlo (VMC)
- Macro Monte Carlo (MMC)
- Superposition Monte Carlo
- Other programs (ITS, MCNP, PENELOPE)
- EGS4/MCRTP/MCDOSE/MCSIM

Commercial Implementation

- Nucletron Oncentra MasterPlan (2001)
  - Implementation of Kawrakow's VMC++ Monte Carlo dose calculation algorithm (2000)
- Varian Eclipse eMC (2004)
  - Based on Neuenschwander's MMC dose calculation algorithm (1992)

Timing – Nucletron Oncentra MasterPlan

- 10x10 cm^2 applicator
- 50k histories/cm^2
- Anatomy - 41 CT slices
- Pentium 4 Xenon 2.2 GHz
- Calculation time
  - 1.5 minutes for 6 MeV beam
  - 8.5 minutes for 20 MeV beam

Faster than pencil beam!

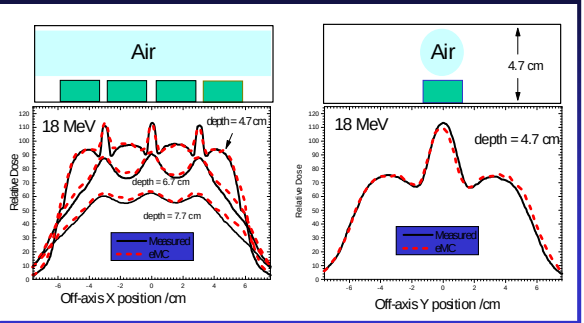
Courtesy of Joanna Cygler

Implementation procedures

- Modeling of clinical electron beams
- Commissioning of clinical electron beams
- CT data and beam setup conversion
- Dose calculation, data processing and display

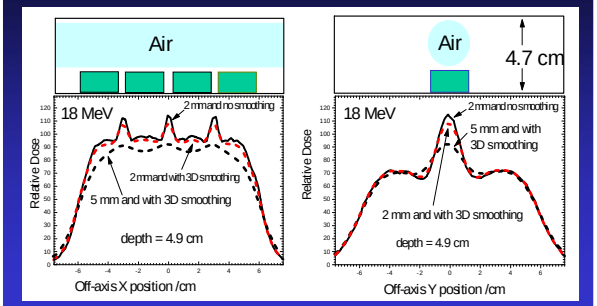
Eclipse eMC no smoothing

Voxel size = 2 mm



Ding et al (PMB 2006)

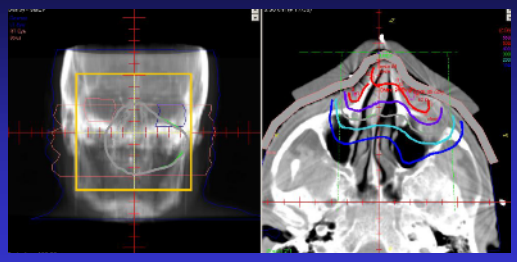
Effect of voxel size and smoothing



Ding et al (PMB 2006)

MU real patient vs.water tank

(MC / Water tank= 292 / 256=1.14)



Courtesy of Joanna Cygler

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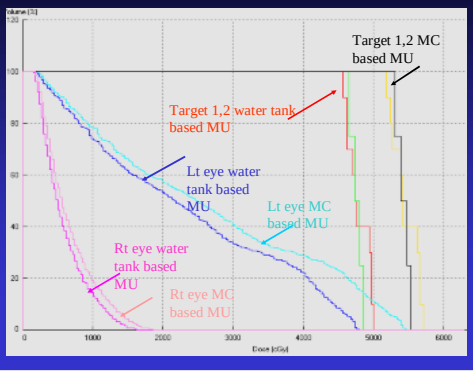
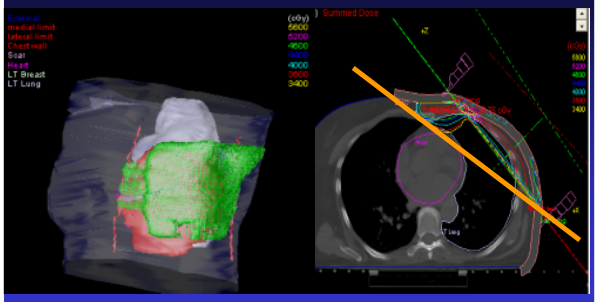


Internal mammary nodes

(MC / Water tank= 210 / 206=1.019)



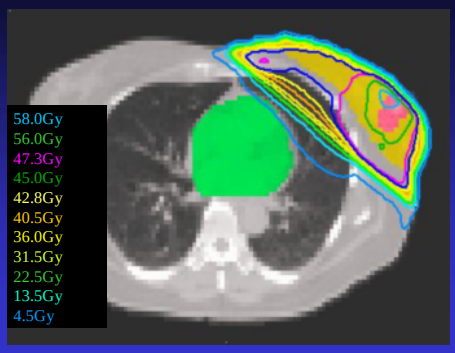
Courtesy of Joanna Cygler

Monte Carlo for Mixed Beam Treatment for Breast

- Conventional (46 Gy, 14 Gy boost)
  - Photon beams to whole breast: 23 fractions, 2 Gy/fraction
  - Electron boost to tumor bed: 7 fractions, 2 Gy/fraction
- Hypofractionated (45 Gy, 56 Gy)
  - IMRT to whole breast: 2.25 Gy x 20 fractions
  - IMRT/MERT to tumor bed: 2.8 Gy x 20 fractions

Courtesy of Jinsheng Li

Combined Photon/Electron Plan Based on MC



Courtesy of Jinsheng Li

Conclusions

- Monte Carlo is a useful tool for radiotherapy treatment planning & dose verification
- Monte Carlo has a more important role in electron dose calculation
- High accuracy, high efficiency, low cost
- More work is needed to make it clinically available