Dosimetry near low-Z/high-Z interfaces

- Effects on attenuation (primary beam) and scatter (fields are typically large)
  - Enhanced attenuation behind high-Z material
  - In-scatter from the unobstructed portion of the beam partially compensates for the loss of dose due to attenuation
- The magnitude and the spatial extent depend on the energy of the radiation as well as the density, atomic number, and dimensions of the inhomogeneity
- For photon beams above 10 MV interactions of contaminant neutrons with the high-Z material

Dosimetric considerations for patients with HIP prostheses undergoing pelvic irradiation. Report of the AAPM Radiation Therapy Committee (Task Group 63) C. Reft et al., Med. Phys. 30, 2003

- Between 1% and 4% of radiotherapy patients have prosthetic devices which could affect the predetermined value of the dose that they would receive
- The purpose of the report is to make the radiation oncology community aware of the problems arising from the presence of these devices in the radiation beam, to quantify the dose perturbations they cause, and, finally, to provide recommendations for treatment planning and delivery
- The scientific understanding and methodology of clinical dosimetry for these situations is still incomplete

TG-63 Report

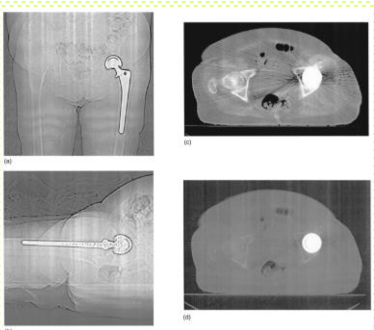


FIG. 4. CT images of a patient with a hip prosthesis (cup, head, and stem): a) frontal image/scout, b) lateral view scout, c) transversal slice showing artifacts, and d) same image as in c), but contrast level adjusted to better visualize the contour of the prosthesis.

TG-63 Report: manual calculations

- Calculation which accounts for primary attenuation only: $I/I_0=e(-\mu t)$
- Scattering can be partially accounted for by using the effective tissue-air-ratio (TAR) or the tissue-maximum-ratio (TMR) methods
  - Correction factor CF to find the dose behind prosthesis (thickness t, density ρ_e relative to water, calculation depth d, field size w)

$$CF = TMR(d', w) / TMR(d, w)$$

$$d' = d - t(1-\rho_e)$$

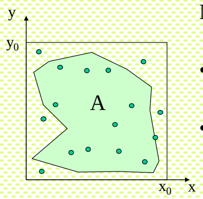
TG-63 Report: manual calculations

- For a 1.6 cm thick Co–Cr–Mo prosthesis located at a depth of 8 cm, the dose correction factors calculated at a distance 10 cm beyond it are 0.68 and 0.78, producing an attenuation of 32% and 22% for incident 6 and 18 MV clinical photon beams, respectively
- If the linear attenuation coefficient method is used, it yields an attenuation of about 37% and 28% for 6 and 18 MV photons, respectively
- The effective TMR method gives less attenuation because it includes a scatter contribution

Monte Carlo technique

- Need to solve a complex mathematical problem, describing physical system
- With Monte Carlo find physical parameters using statistical sampling: problem variables are obtained by selecting values from the appropriate range, using probability distributions for such variables
- Based on the use of sequences of random numbers to obtain sample values for the problem variable; the calculation process involves a computer program
- Somewhat equivalent to conducting experiment:
  - Yields a result that is a possible outcome of the modeled process
  - Associated uncertainty can be reduced by increasing a number of attempts

Monte Carlo technique: example



Need to find area A of irregularly-shaped object

- Define an enveloping rectangle with sides x_0 y_0 and area $A_0 = x_0 * y_0$
- Generate N_0 **random** points with coordinates $(x, y) < (x_0, y_0)$ and count N_{inside} - points falling inside
- $A = A_0 * (N_{inside}/N_0)$
- N_0 defines accuracy

TG-63 Report

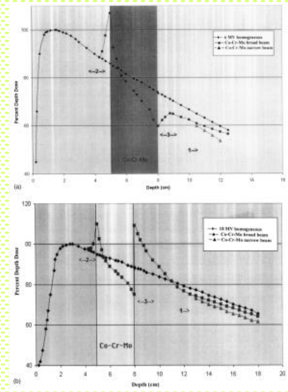
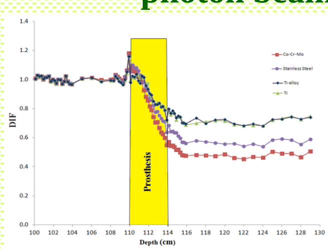


FIG. 1. Dose perturbation near and far from a Co–Cr–Mo inhomogeneity.
a) and b) show the perturbation to the central axis percentage depth dose for 6 and 18 M beams incident on a 3 cm thick Co–Cr–Mo slab inhomogeneity. Region 1 is greater than d_{max} from the implant and zones 2 and 3 are at the proximal and distal ends of the implant, respectively.

6MV vs. 18MV: pair productions contribution at higher energy

Hip prostheses under 15MV photon beam

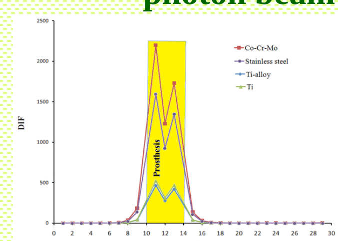


Dose increase factor (DIF) vs. depth for **electron contamination** in presence of hip prostheses in the 15 MV photon beam pathway for the four hip prostheses: Co-Cr-Mo, stainless steel, Ti, and Ti-alloy

Z(Ti)=22
Z(Fe)=26
Z(Co)=27, Z(Cr)=24, Z(Mo)=42

Toossi et al., A Monte Carlo study on electron and neutron contamination caused by the presence of hip prosthesis in photon mode of a 15 MV Siemens PRIMUS linac, Journal of Applied Clinical Medical Physics, Vol 14, (2013)

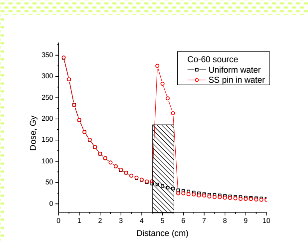
Hip prostheses under 15MV photon beam



Dose increase factor (DIF) vs. depth for **neutron contamination** in presence of hip prostheses in the 15 MV photon beam pathway for the four hip prostheses: Co-Cr-Mo, Stainless steel, Ti-alloy, and Ti.

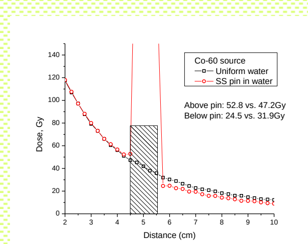
Toossi et al., A Monte Carlo study on electron and neutron contamination caused by the presence of hip prosthesis in photon mode of a 15 MV Siemens PRIMUS linac, Journal of Applied Clinical Medical Physics, Vol 14, (2013)

Problem 11-11: SS pin in tissue under Co-60 beam



- 1 cm SS pin inserted in tissue
- Dose 40Gy in homogeneous tissue
- Results of MC simulation for 1D geometry

Problem 11-11: SS pin in tissue under Co-60 beam



- Due to small size of the pin its effect on the dose above and below is not very significant