Monitor Unit Calculations – Part 3

George Starkschall, Ph.D.
Department of Radiation Physics
U.T. M.D. Anderson Cancer Center

Calculation of machine setting

\[
\text{machine setting} = \frac{\text{reference dose}}{\text{reference dose output}} \times \text{correction for collimator setting} \times \text{correction for distance from source} \times \text{correction for beam modifiers} \times \text{correction for attenuation and scatter}
\]

Percent depth dose (PDD, %dd)

• Two types of patient set-ups
  – Isocentric set-ups
  – Fixed SSD set-ups
Percent depth dose (PDD, %dd)

- **Isocentric set-ups**: center of tumor (treatment volume) placed at isocenter – TAR logical quantity to use

- **Fixed SSD set-ups**: entry point of beam is placed at fixed distance from source (usually the isocenter)
  - Center of treatment volume then at SSD+d from source
  - TAR not as convenient to use for calculations

Percent depth dose (PDD, %dd)

- Let
  - \( D_n \) – dose delivered to small mass of tissue at depth within patient
  - \( D_0 \) – dose delivered to same mass of tissue at a depth \( d_{max} \), keeping SSD same
- **PDD defined as**
  \[
  PDD = \left( \frac{D_n}{D_0} \right) \times 100\%
  \]
Percent depth dose (PDD, %dd)

\[
PDD = \left( \frac{D_n}{D_0} \right) \times 100\%
\]

Example:

- Calculate treatment time required to deliver 150 cGy to point 7 cm below surface using 8 cm \( \times \) 8 cm \(^{60}\)Co beam at SSD of 80 cm with dose rate of 135.3 cGy/min at \( d_{\text{max}} \).

- Prescribed dose – 150 cGy
- PDD for 8 cm \( \times \) 8 cm \(^{60}\)Co beam at depth of 7 cm is 67.6%
- Given dose is

\[150 \text{ cGy}/0.676 = 222 \text{ cGy}\]
Percent depth dose (PDD, %dd)

- Dose rate at $d_{\text{max}}$ is 135.3 cGy/min so treatment time is
  
  $\frac{222 \text{ cGy}}{135.3 \text{ cGy/min}} = 1.61 \text{ min}$

Percent depth dose (PDD, %dd)

- Effect of depth:
  - In buildup region (depths $< d_{\text{max}}$) PDD increases with increasing depth

Percent depth dose (PDD, %dd)

- Effect of depth:
  - At $d_{\text{max}}$, PDD is 100%
  - Beyond $d_{\text{max}}$, PDD decreases with increasing depth due to beam divergence and attenuation
**Percent depth dose (PDD, %dd)**

- **Effect of beam quality:**
  - Depth of central axis maximum increases with beam energy
  - Beyond $d_{max}$, PDD at given depth increases with increasing beam energy

- **Effect of field size:**
  - For given beam energy, PDD increases with field size, because larger area from which radiation can be scattered

- **Effect of SSD:**
  - As SSD increases, dose rate decreases
  - As SSD increases, PDD increases because effect of beam divergence reduced
Percent depth dose (PDD, %dd)

- Find PDD tables:
  - For $^{60}$Co – BJR, Supplement 25
  - For specific linacs – physics data notebook for specific machine
  - Important to use correct table for appropriate machine and for appropriate SSD, because PDD is dependent on SSD

Tissue-maximum ratio (TMR)

- Although TAR useful for treatment time calculations, limits to applicability result from need to measure in-air dose rate
  - For $^{60}$Co energies or lower, in-air measurements not a problem
  - For high photon energies, in-air measurements extremely difficult

- Use a large amount of buildup material on ionization chamber
  - Produces scattered radiation
  - For small fields, buildup cap may not necessarily be completely included in field
- Other quantity needed to replace TAR for high-energy photons
**Tissue-maximum ratio (TMR)**

- Make reference measurement in phantom at depth $d_{\text{max}}$
  - Ratio is *tissue maximum ratio (TMR)* defined by

$$TMR = \frac{D(\text{depth})}{D(d_{\text{max}})}$$

**Tissue-maximum ratio (TMR)**

- Definition of TMR directly related to calibration procedure for photon beams
  - Express calibrated dose rate of photon beam at standard field size at depth of $d_{\text{max}}$
Tissue-maximum ratio (TMR)

Example:
• 6 MV linac calibrated to deliver 1 cGy/MU for 10 cm × 10 cm field at depth of d_max at 100 cm from source
• For 12 cm × 16 cm field
  – Output factor = 1.010
  – TMR at depth of 8 cm = 0.887

Example:
• Calculate monitor units to deliver 300 cGy to 12 cm × 16 cm field at midline using parallel opposed fields at SAD of 100 cm
• The patient thickness is 16 cm

Tissue-maximum ratio (TMR)

Example:
• Dose rate at d_max for 10 cm × 10 cm field – 1 cGy/MU
• Dose rate at d_max for 12 cm × 16 cm field is 1 cGy/MU × 1.010 = 1.010 cGy/MU
• Dose rate at 8 cm depth for 12 cm × 16 cm field is 1.010 cGy/MU × 0.887 = 0.896 cGy/MU
**Tissue-maximum ratio (TMR)**

- To deliver 150 cGy/field, monitor units required is

\[
\frac{150 \text{ cGy}}{0.896 \text{ cGy/MU}} = 167 \text{ MU}
\]

- TMR must be measured for each radiation machine
  - Best source of TMR data: physics data book (or file) for particular treatment machine

**Tissue-phantom ratio (TPR)**

- Use dose rate at specified depth as reference measurement
  - Tissue phantom ratio (TPR) defined as

\[
TPR = \frac{D(\text{depth})}{D(\text{ref depth})}
\]