Clinical Reference Dosimetry of a "Hi-Art II Helical Tomotherapy Machine

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Statement of the Problem

- Factory sets the dose rate, not the local physicist.
- Rigorous implementation of TG-51 not possible.
- Can not meet state regulations to perform an annual calibration.

WHY?

TG-51 requires a beam quality to be defined at 100 cm SSD, 10 x 10 cm^2, 10 cm depth.

Tomotherapy unit has physical limitations/differences

1. 85 cm SAD
2. Maximum field size 40 x 5 cm^2
3. Un-flattened beam
4. Different energy spectrum

Bottom line:

TG-51 reference conditions can not be met

Proposed Methodology

1. Measure the ionization ratio (TPR_{10}^{20}) for 85 cm SAD, 40 x 5 cm^2 (eq. sq. 8.3 x 8.3)

Nominal Energy	4 MV	Tomo. 6 MV	6 MV
IR	0.615	0.635	0.672
dmax	1.2 cm	1.3 cm	1.5 cm

Proposed Methodology

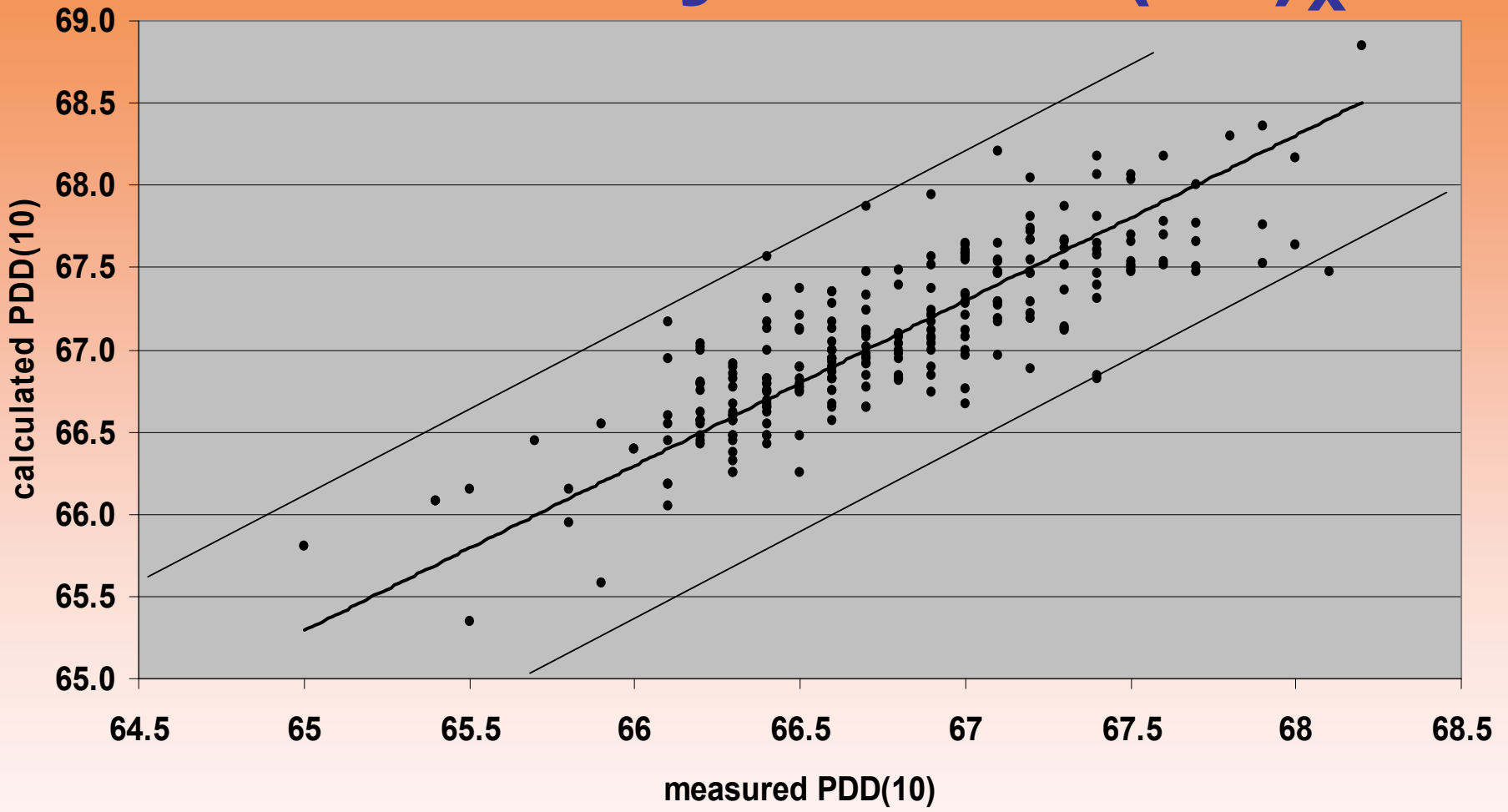
2. Calculate the $\%dd(10)_x$ using the empirical relationship published in the IAEA TRS 398 protocol.

Independent of SSD

$$\%dd(10)_x = 98.34(TPR_{10}^{20})^2 - 39.084(TPR_{10}^{20}) + 49.093$$

Gives you an equivalent $\%dd(10)_x$ for 100 cm SSD, 8.3 x 8.3 cm^2, 10 cm depth

Uncertainty in $\%dd(10)_x$



Range of calc. values ⇨ 0.2% uncertainty in k_Q

Additional Uncertainty in k_Q

Measurement for 40 x 5 (eq. sq. 8.3) instead of 10 x 10 as required by TG-51.

Standard linac, 6 MV x-ray beam.

	10 x 10	10 x 10	40 x 5
	measure %dd(10)	measure TPR calc. %dd(10)	measure TPR calc. %dd(10)
$\%dd(10)_x$	66.8	67.1	66.5
k_Q	0.995	0.995	0.996

Field size difference ⇨ 0.1% uncertainty in k_Q

Proposed Methodology

3. Perform the calibration measurement at d_{max} or 10 cm depth.

   - calibration at d_{max} reduces the uncertainty introduced using the clinical depth dose.

   - calibration at d_{max} increases the uncertainty in the k_Q value minimally(<0.05%).

   - calibration at 10 cm depth more closely follows the TG-51 protocol and reduces the uncertainty in k_Q.

Other Proposed Techniques and Uncertainties Associated with each

	Jeraj et. al.	Thomas et. al.	RPC
Measured Dose Rate (cGy/min)	**879.6**	**885.6**	**882.7**
For 10 x 5 cm^2 0.997±0.001	Look up $\%dd(10)_x$ for 100 cm SSD, 10 x 10	Calc $\%dd(10)_x$ for 100 cm SSD, 8.3 x 8.3	
Change in k_Q (ref vs meas) 0.996 – 0.998			
K_{tot} Correction for 10 x 5 0.994 – 0.997	Change in k_Q (ref vs meas) 0.998 - 0.999	Determine k_Q ↑ Uncertainty 0.3%	

TLD Verification

Dosimeter	RPC	Institution	RPC/Inst. ratio
Ion chamber	882.7 cGy/min	890.6 cGy/min	0.991
TLD block (n=4)	444.8 cGy (±1.9)	444.9 cGy	1.000
TLD cylinder (n=7)	198.7 cGy (±1.3)	200 cGy	0.993

Summary

1. Three methods exist to perform reference dosimetry on the Hi-Art Helical Tomotherapy machine.
2. All 3 methods give dose rates that are within 0.5% of each other.
3. The RPC can verify the calibration with its TLD program either with the cylindrical or block phantom.

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