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Determination of beam quality index, $TPR_{20/10}$, on the NPL Elekta linac

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ABSTRACT

Beam quality index, $TPR_{20/10}$ for the NPL Elekta linac was determined for each of the seven available photon energies, 4 – 25 MV.

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CONTENTS

1 INTRODUCTION

The IPSM Code of Practice for high-energy photon beams (IPSM 1990) recommends the tissue-phantom ratio, $TPR_{20/10}$, as a specifier of the quality of a high-energy photon beam. In most radiation dosimetry protocols, such as the IAEA technical report TRS 398 (2000), IAEA technical report 277 (1987) and NCS (1986), $TPR_{20/10}$ is recommended as the beam quality specifier of choice. The $TPR_{20/10}$ is the ratio of ionisation measurements at 20 cm and 10 cm depth in water for a constant source to chamber distance and with a 10 x 10 cm field at the plane of the detector. Strictly it is the ratio of absorbed dose at the two depths, but as stopping power ratios and other factors do not change much with depth the ratio of ionisation at the two depths gives an acceptably accurate value (Kosunen and Rogers, 1993). It is a measure of the effective attenuation coefficient describing the approximately exponential decrease of a photon depth-dose curve beyond the depth of maximum dose (Brahme and Andreo, 1986) and more importantly, it is independent of the electron contamination in the incident beam.

The term 'beam quality' is used to indicate the ability of a beam to penetrate a water phantom. The x-ray beam's penetrative ability is a function of the beam's spectrum. Various parameters are used as beam quality specifier. However, it is not possible to use a given specifier in the whole energy range of interest in clinical physics, from superficial x-rays to high-energy megavoltage x-rays. Known x-ray beam quality specifiers or indices include the half-value layer (HVL), nominal accelerating potential (NAP), tissue-phantom ratio (TPR) and percentage depth dose (PDD).

2 METHODS AND MATERIALS

2.1 NPL LINAC

The NPL Elekta linac was installed in October 2008. It is a Synergy model with seven available photon energies. These are in three 'handbags' with each handbag having three energies. The combinations are as follows:

- Handbag 1: 6, 10, 15 MV
- Handbag 2: 6, 10, 25 MV
- Handbag 3: 4, 8, 18 MV

Beams from the NPL Elekta linac were collimated to produce a 10 cm x 10 cm field at a source-to-chamber distance (SCD) of 100.0 cm using the MLCi leaves and backup diaphragms.

2.2 PHANTOM SET UP

The original assessments of $TPR_{20/10}$ were measured in a solid water phantom (WTe). The results were then repeated in later work using the new NPL calibration water phantom. An NPL-owned calibrated secondary standard ionisation chamber of type NE2611 was used to measure the $TPR_{20/10}$. In both cases the phantom was set up on the carriage in the exposure room and a mirror was used in conjunction with the field light to ensure that both phantoms were perpendicular to the beam. The optical distance indicator (ODI) was used to determine the source-surface distance (SSD). The chamber was positioned at the isocentre (source-chamber distance, SCD, of 100.0 cm) for all measurements.

The WTe measurements used a vertical beam. The NPL Elekta linac gantry was set to 0.0°, the collimator angle was set to 0.0°. 130 mm of polystyrene was placed under the WTe phantom to provide extra backscatter. The ionisation chamber depth in the phantom was positioned using different thicknesses of WTe sheets. For measurements at 10.0 cm depth the ODI was used to position the front face of the phantom at 90.0 cm.

The water phantom measurements used a horizontal beam. The phantom was filled with demineralised water. The NPL Elekta linac gantry was set to 90.0°, the collimator angle was set to 0.0°. The chamber in its waterproof sleeve was placed in the chamber holder in the calibration phantom and the linac field light used to position the effective point of measurement of the ionisation chamber on axis. Throughout the measurements the axis of the ionisation chamber was positioned perpendicular to the axis of the horizontal beam. The effective point of measurement for positioning the chamber was taken to be on the chamber axis: 5 mm from the tip of a NE2611 chamber type.

2.3 WATER PHANTOM POSITIONING

The new NPL calibration phantom has a computer-controlled positioning device and enables a chamber to be positioned at any depth. The chamber was positioned at a depth of 5.0 cm in water and this was checked using the '4-10MV' measuring bar. An internal micrometer was used between the linac front pointer holder and the front of the water phantom to position the phantom so that the source-to-chamber distance (SCD) was 100.0 cm. The phantom carriage control program *carriage control.exe* was then used to move the phantom forward by 5.0 and 15.0 cm, putting the chamber at a depth of 10.0 and 20.0 cm but maintaining the chamber position at the isocentre. These depths were stored in the program's memory.

2.4 CHAMBER MEASUREMENTS

The ionisation chamber was connected to a calibrated electrometer and, at each of the seven available linac energies, 100 MU was delivered to the chamber. The charge collected by the chamber was recorded. At least five measurements of this type were performed at both 10.0 and 20.0 cm depth at each energy. Measurements were accepted when there was no trend within the readings and the standard deviation was less than 0.1%. For each linac energy the pulse repetition frequency (PRF) and dose rate were used to determine the ion recombination. All charge readings were corrected for linearity and charge calibration of the electrometer, for ion recombination, and to standard conditions of 20.0°C and 1013.25 mbar.

2.5 CALCULATION OF $TPR_{20/10}$

The $TPR_{20/10}$ was determined by taking the ratio of the ionisation at 20.0 cm depth to that at 10.0 cm depth.

3 RESULTS

The beam quality indices, $TPR_{20/10}$, measured at each of the seven available photon energies on the NPL Elekta linac are given in table 1. These results were determined in the NPL calibration water phantom. Those determined in a WTe phantom showed no significant differences.

Table 1. The beam quality indices, $TPR_{20/10}$, measured in water at seven photon energies on the NPL Elekta linac. The uncertainty on the beam quality index is ±0.2%.

Nominal beam energy (MV)	Quality Index, $TPR_{20/10}$
4	0.633
6	0.682
8	0.713
10	0.733
15	0.758
18	0.775
25	0.800

4 CONCLUSION

The beam quality indices $TPR_{20/10}$ were measured in water at seven available photon energies on the NPL Elekta linac.

5 ACKNOWLEDGEMENTS

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