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On the time constancy and accuracy of a therapeutic kV x-ray system calibration

L. Papakonstantinou[1]

[1]Department of Physics, University of Athens

1. Background-Aim

- To assess the long-term output calibration constancy of a therapeutic kV x-ray system calibrated in terms of dose to water at the surface of a water phantom, $D_{w,z=0}$.
- Evaluate the changes brought about by new sources of data required for this calibration.

<u>Images</u>: In the left image, the ionization chamber is centered within the radiation field. Subsequently, the x-ray tube is locked in place along the x and y axes and moved along the z axis.

Aluminum filters are then inserted to achieve the necessary geometry for measuring the Half-Value Layer (HVL).

2. Materials & Methods

A Farmer-type ionization chamber (A12 REF 92700, EXRADIN) paired with a PTW UNIDOS electrometer was used for x-ray beam dosimetry.

The chamber had been previously calibrated in air based on beam energy, ensuring measurement stability. The x-ray beam quality was determined through Half-Value Layer (HVL) measurements using aluminum and copper filters.

Measurements were conducted at a 100 cm distance from the source, using a lead collimator to shape the radiation field.

For each filter of the system, measurements were taken without any absorber (Y_0), representing the direct exposure, as well as with varying absorber thicknesses (x_i) placed in the beam at the level of the lead collimator (Y_i).

The Half-Value Layer (HVL) of the primary radiation for each filter was calculated using the two intensity values, Y_1 and Y_2, that surrounded the value of $Y_0/2$, based on the followed the equation:

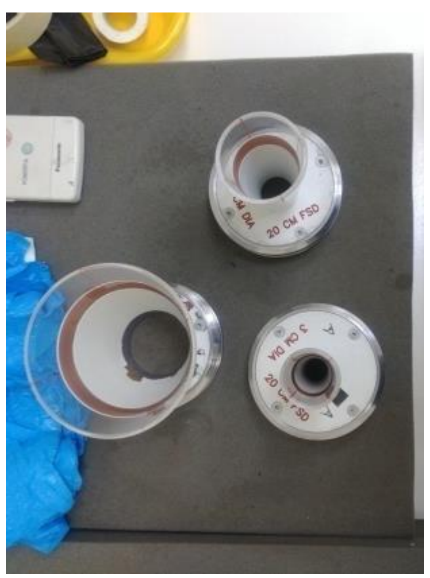
$$HVL = \frac{x_1 \cdot \ln\left(\frac{2Y_2}{Y_0}\right) - x_2 \cdot \ln\left(\frac{2Y_1}{Y_0}\right)}{\ln\left(\frac{Y_2}{Y_1}\right)}$$

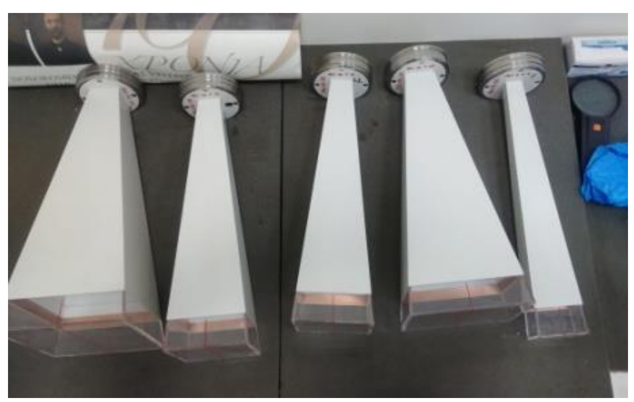
2. Materials & Methods

Ionometry was performed for 4 applicators and 9 filters of the system using a Farmer type chamber with an air kerma calibration, N_K.

The same chamber was used to measure the HVL for the 9 beam qualities.

Data required to obtain $D_{w,z}$=0 (the ratio of mass energy absorption coefficients in water and air, $\left(\frac{\bar{\mu}_{en}}{\rho}\right)_{air}^{w}$, and water backscatter factors, BSF) were obtained by two sources: Ma et al 2001 (doi: 10.1118/1.1374247) and Andreo 2019 (doi: 10.1088/1361-6560/ab421d).





Images: Open and closed type applicators

Image: Farmer-type ionization chamber

Image: PTW UNIDOS electrometer

3. Results

Within a decade, the chamber N_K increased by 1.2%. The ionization charge per MU measured for the beam qualities remained within 1.5% with secondary chamber daily measurements exhibiting no trend.

HVL measurements differed up to 8% from the ones used for initial system calibration, leading <2% changes in N_K and for the different filters, and noticeable differences in the corresponding BSFs (within -8% and 5%). Collectively, these would lead to differences in $D_{w,z=0}$ calibration within -7% and 6%.

New and BSFs data in the literature differ from old ones by <1% and -3%, respectively. Use of the new data would lead to differences in $D_{w,z=0}$ calibration within -3% and 2%.

3. Results

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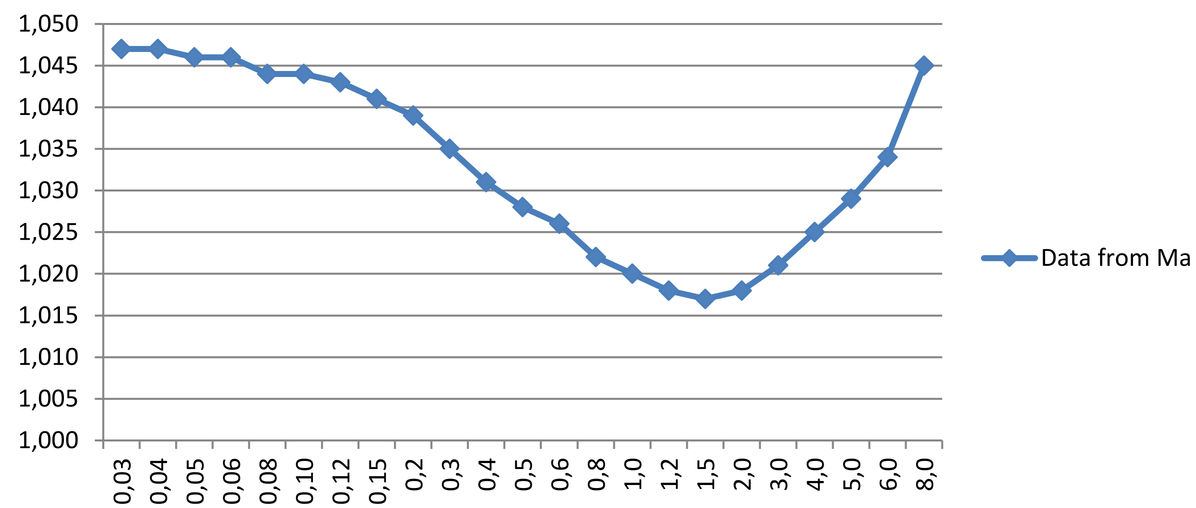
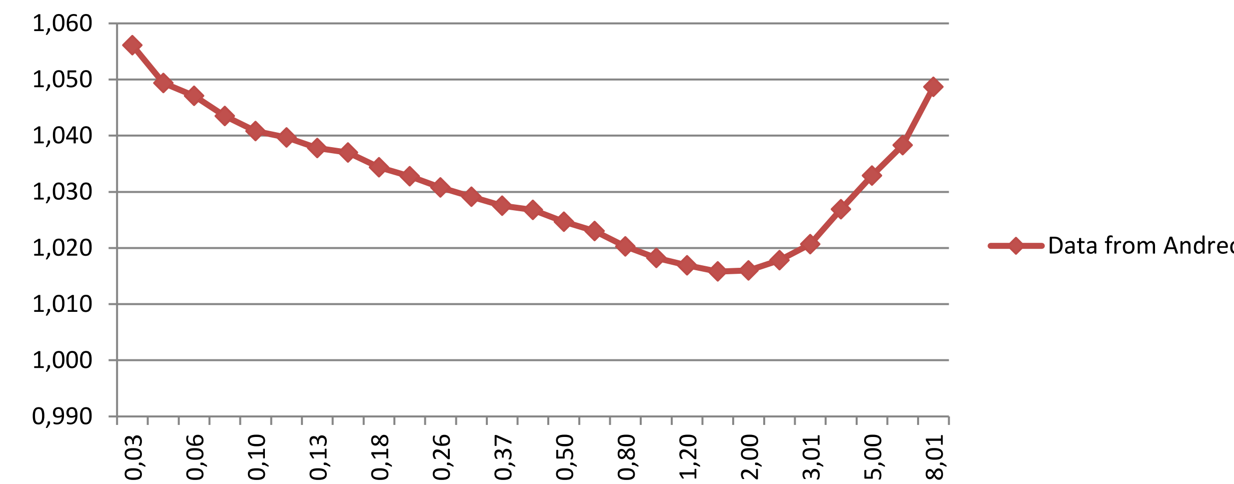
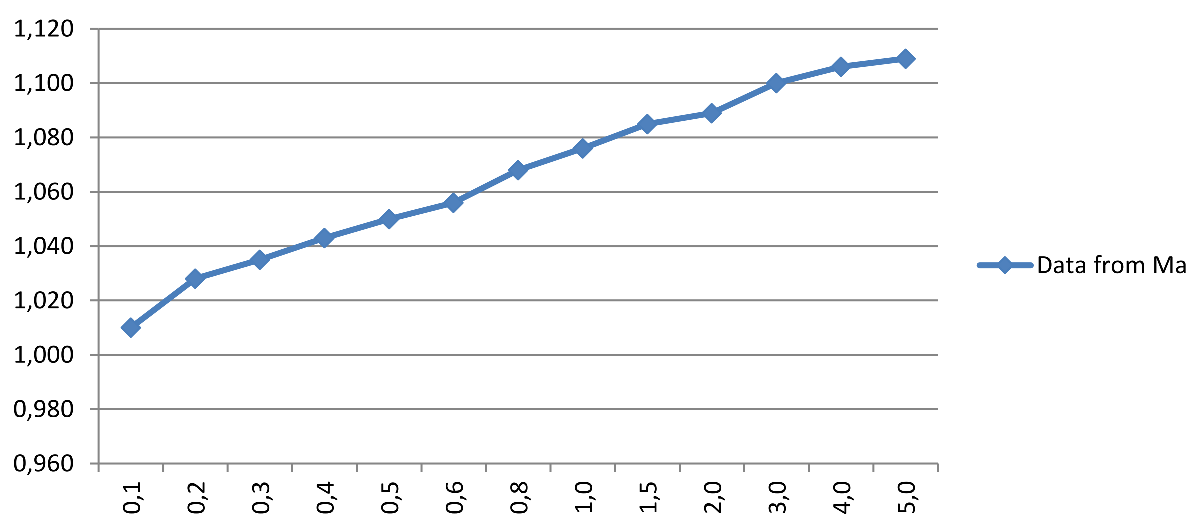
<u>Graph 1</u>: Mean mass energy-absorption coefficient ratio of water to air as a function of HVL (mm Al) [1]



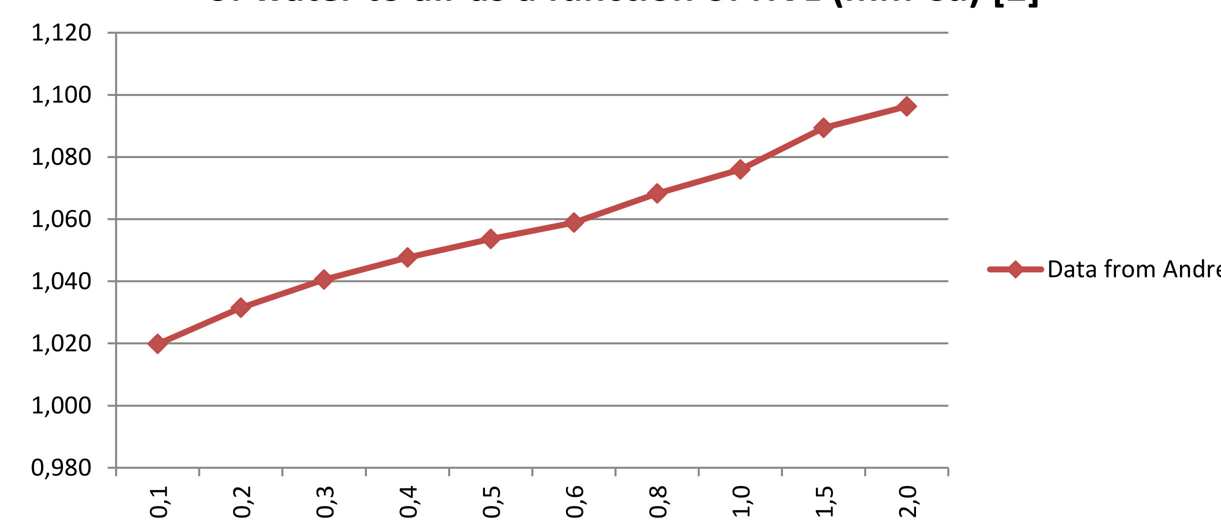
<u>Graph 2</u>: Mean mass energy-absorption coefficient ratio of water to air as a function of HVL (mm Al) [2]



<u>Graph 3</u>: Mean mass energy-absorption coefficient ratio of water to air as a function of HVL (mm Cu) [1]



<u>Graph 4</u>: Mean mass energy-absorption coefficient ratio of water to air as a function of HVL (mm Cu) [2]

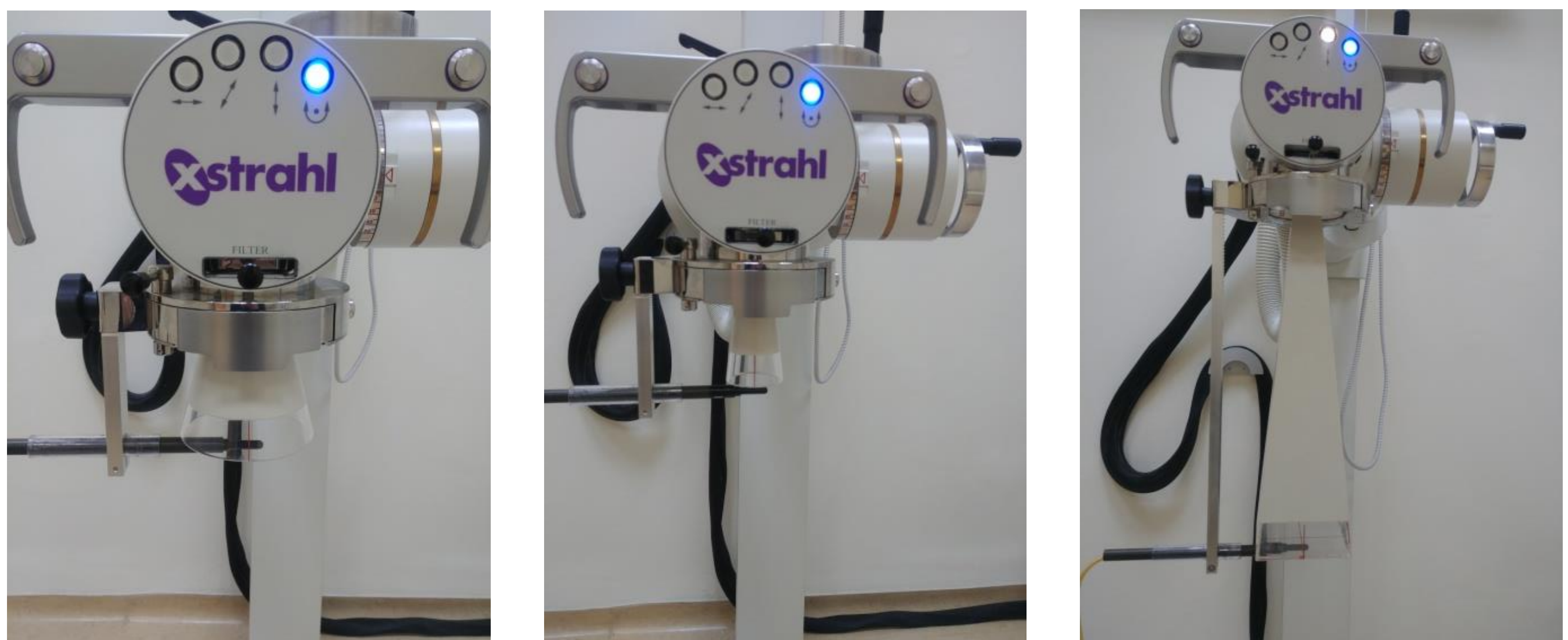


4. Conclusions

The change in measured HVL leads to calibration changes, mainly due to the change in BSFs, which is within uncertainties (7%, k=2).

The new data available lead to small calibration differences well within uncertainties.

The system exhibits remarkable constancy and adhering to international recommendations for periodic quality assurance guarantees accuracy.



<u>Images</u>: Irradiation of the chamber using different applicators (in the third image, a closed-type applicator is used)

5. References

1. Ma C-M, Coffey CW, DeWerd LA, et al. AAPM protocol for 40-300 kV x-ray beam dosimetry in radiotherapy and radiobiology. *Med Phys. 2001;28(6):868-893. doi: 10.1118/1.1374247*
2. P. Andreo, “Data for the dosimetry of low – and medium- energy kV x-rays, *“Physics in Medicine and Biology, vol. 64. IOP Publishing, pp. 1-19, 2019. doi: 10.1088/1361-6560/ab421d.*