X-Ray Multimeter Performance in Diagnostic Imaging Calibration Beams

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INTRODUCTION

- X-ray multimeters (XMMs) are solid-state dosimeter systems designed for measurements of diagnostic radiology and mammography beams.
- The manufacturer-provided software uses readings from multiple diodes to estimate beam quantities such as tube potential, air-kerma rate, and half-value layer (HVL). Other groups have investigated the performance of these detectors in various clinical and calibration beams [1,2].
- Calibrations are performed by the manufacturers and a nationally-standardized process does not currently exist.
- **This study expanded upon the existing body of work by analyzing the performance of two XMMs in tungsten- and molybdenum-anode calibration beams that are matched in HVL with beams at the National Institute of Standards and Technology.**

MATERIALS AND METHODS

- The two XMMs investigated in this study were an RTI (Mölndal, Sweden) Piranha and a Radcal (Monrovia, CA) Accu-Gold+ with AGMS-DM+ sensor. The XMMs are shown in **Figure 1**.
- XMM performance was evaluated in the University of Wisconsin (UW) M- and MO-series beams at the UW Accredited Dosimetry Calibration Laboratory. All beams have been matched in terms of HVL with calibration beams at the National Institute of Standards and Technology (NIST).
  - The UW M-series beams: stationary tungsten-anode x-ray tube, aluminum and aluminum-copper filters, and 60-150 kV tube potentials.
  - The UW MO-series beams: molybdenum-anode x-ray tube, molybdenum filter, and 23-35 kV tube potentials.
- Measurements of tube potential, air-kerma rate, and HVL were performed for all beams.
- The point-of-measurement was located one meter from the source, centered in a 10 x 10 cm^2 field.

Figure 1. RTI Piranha (left) and Radcal Accu-Gold+ (top) with AGMS-DM+ sensor (right).

RESULTS

- Plots of measured vs. reference tube potentials, air-kerma rates, and HVLs are shown in **Figures 2-4**. Error bars indicate the manufacturer-stated uncertainties.
- Measurements with the Piranha did not agree within the manufacturer-stated uncertainty of the set tube potential for the UW MO-series, UW100-M, and UW120-M beams. The AGMS-DM+ showed similar results for the UW100-M, UW120-M, and UW150-M beams.
- Air-kerma rate measurements were significantly better, with all measurements showing agreement with the reference values.
- All HVL measurements agreed with reference values other than the AGMS-DM+ measurement for the UW60-M beam. This measurement likely had the largest deviation because the selected tube potential was near the minimum tube potential for the selected operating settings.
- The data displayed in **Figures 2-4** was collected in December 2022. The same measurements were also performed in September 2022.
- **Table 1** lists the maximum percent change between measurements taken at those times.
- All changes are less than the uncertainty of the measurements, as specified by the manufacturer or assumed from the natural variation of the tube output.

Table 1. Maximum percent change of measurements from data collected between September and December 2022.

XMM	Tube Potential	Air-kerma Rate	HVL
Piranha (UW M-Series)	0.50%	0.28%	0.14%
Piranha (UW MO-Series)	0.06%	0.87%	0%
AGMS-DM+ (UW M-Series)	0.08%	0.09%	0.04%
AGMS-DM+ (UW MO-Series)	0.33%	1.08%	0.36%

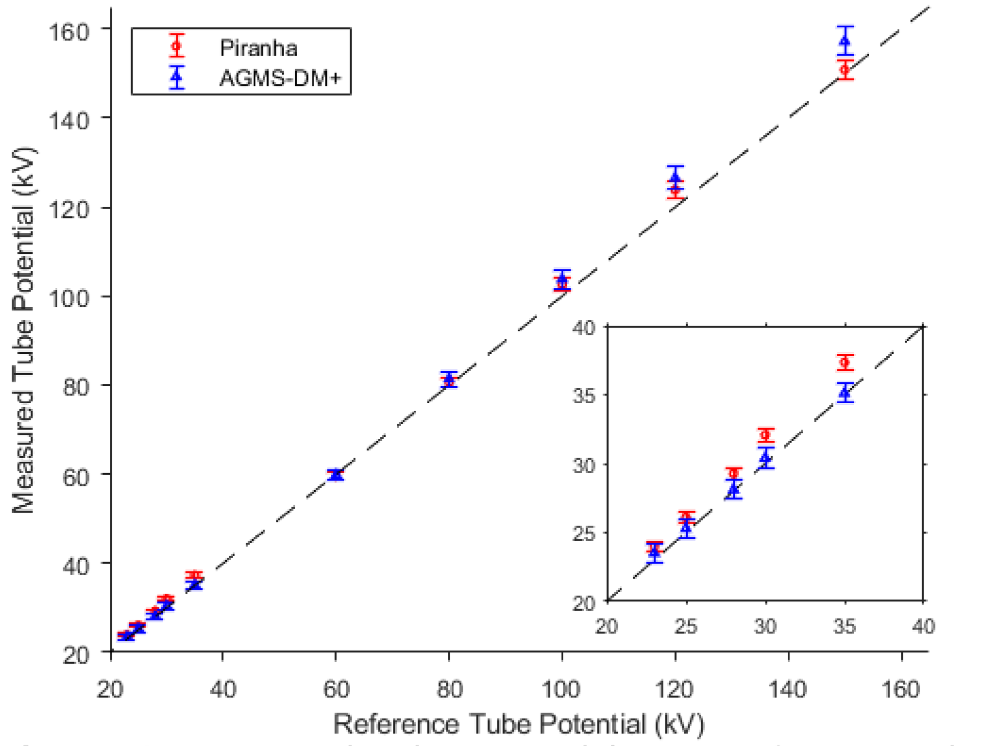

Figure 2. Measured tube potentials vs. reference tube potentials. The inset figure shows the range from 20 to 40 kV.

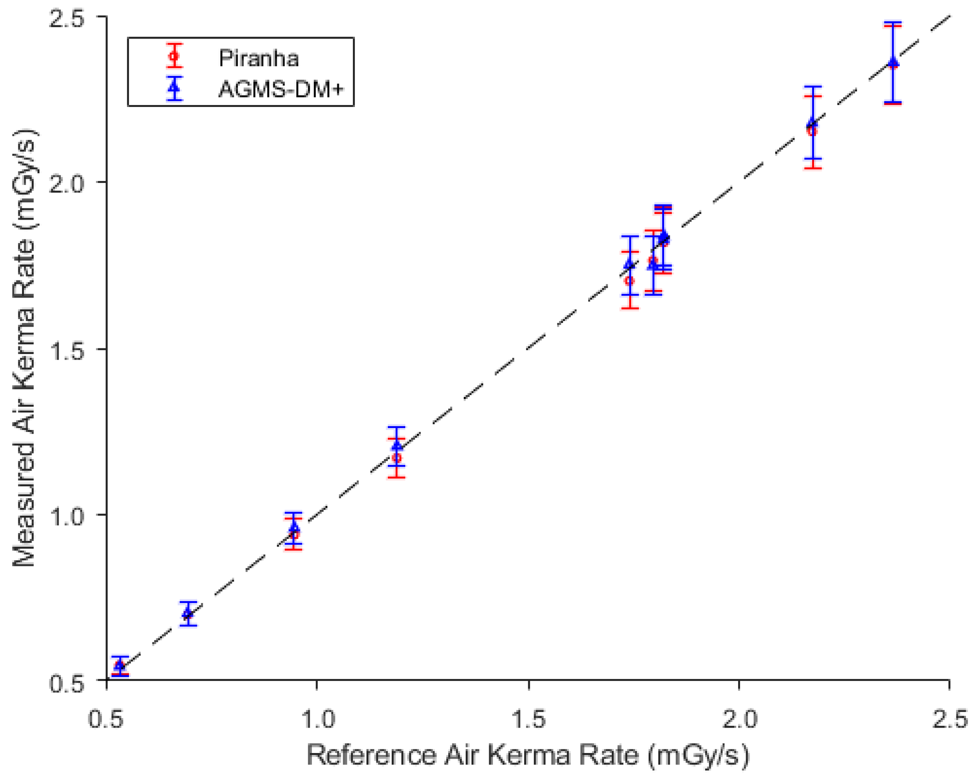

Figure 3. Measured air-kerma rates vs. reference air-kerma rates.

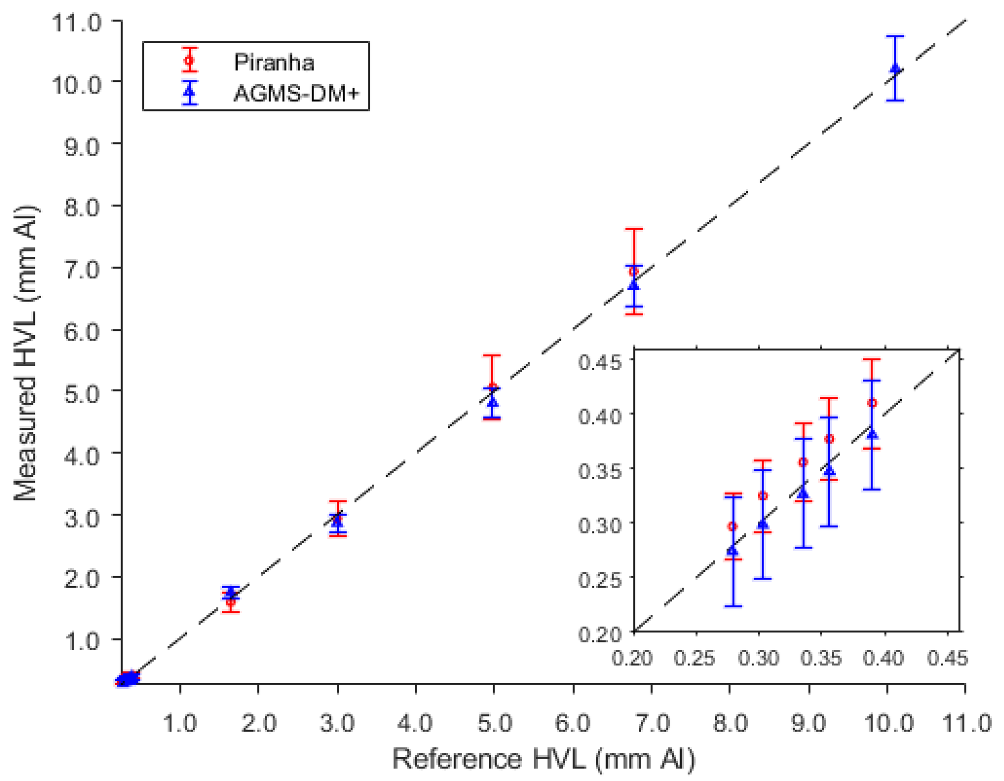

Figure 4. Measured HVLs vs. reference HVLs. The inset figure shows the range from 0.20 to 0.46 mm Al.

CONCLUSION

- Establishing NIST-traceable calibrations for XMMs is vital to ensuring long-term dosimeter performance and more accurate dose estimates for diagnostic imaging, which is important for patient safety.
- **This study generated the first performance data of these XMMs in NIST-matched calibration beams. Measurements generally agreed with the reference values, except for measurements of tube potential.**
- The multimeters tended to display a systematic over or under response for measurements in the UW MO-series beams, indicating that applying a calibration factor would improve the accuracy of measurements using these devices.
- Future work will involve further evaluating the repeatability of measurements and the constancy of the manufacturer calibrations. Measurements in tungsten-anode mammography calibration beams are also planned.
- The data acquired in this study will aid in developing an optimal calibration process. The effect of applying calibration factors to measurements with these multimeters will be evaluated.

REFERENCES

[1] L. Brateman, P. Heintz, “Solid-state dosimeters: A new approach for mammography measurements,” Med. Phys. 42, 542-557 (2015).

[2] E. Salomon, P. Homolka, I. Csete, P. Toroi “Performance of semiconductor dosimeters with a range of radiation qualities used for mammography: A calibration laboratory study,” Med. Phys. 47, 1372-1378 (2020).

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