2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

Five-Year Reliability Assessment of In-Air Film Dosimetry Approach for Quality Assurance of Cs-137 blood Irradiators

Neerajan Nepal, PhD and Sang Hyun Cho, PhD
The University of Texas MD Anderson Cancer Center

ABSTRACT

Purpose: To assess the long-term reliability of *in-air* film dosimetry approach for quality assurance (QA) of Cs-137 blood irradiators using the measured data accumulated over 5 years.

Methods: A new approach based on *in-air* film dosimetry was developed in 2021 to replace the conventional approach based on *in-water* film dosimetry for periodic QA of Cs-137 blood irradiators. In the new *in-air* film dosimetry approach, the air-to-water dose conversion factors were derived from *in-water* and *in-air* film measurements performed sequentially using the custom-made film cassette made of two thin Lexan sheets contained seven dose measurement regions; one at the center and six at off-center locations (2.5 and 5 cm lateral to the center, and 8 cm above and below the center). Specifically, a GAFChromic EBT3 film was sandwiched within the cassette and placed vertically inside the canister. The canister was filled with water for standard *in-water* measurements and left empty for *in-air* measurements. Since its introduction, the new *in-air* film dosimetry approach has been successfully applied to periodic QA of commercial Cs-137 blood irradiators, providing immediately realizable benefits such as relatively simple, quick, and hassle-free measurements, compared to *in-water* film measurements. In this work, the long-term reliability of the new approach was assessed based on analysis of our *in-air* measurement results accumulated over the past 5 years as well as comparison with independent *in-water* measurement results available from commercial dose mapping service providers.

Results: The central dose rate measured *in-air*, after conversion to that in water, agreed well (within ~1%) with the reference data. The off-center %doses also agreed well (within ~3%) with the reference data.

Conclusions: The new *in-air* film dosimetry approach was found to result in consistently good agreement over the past 5 years with the reference data, confirming its effectiveness/robustness for periodic QA of Cs-137 blood irradiators.

CONTACT

Sang Hyun Cho, PhD
UT MD Anderson Cancer Center
Houston, TX 77030
Email: scho@mdanderson.org
Phone: 713-792-5864

INTRODUCTION

- Quality Assurance (QA) of commercial Cs-137 blood irradiators traditionally relies on dosimetry measurements in water or water-equivalent gel.
- *In-water* measurements are cumbersome and prone to unexpected complications, such as water spills before/during/after measurement and water leaks from the stainless-steel canister caused by structural fatigue after years of use.
- These issues introduce unpredictable delays into the QA workflow.
- In 2021, we developed an *in-air* film dosimetry approach [1] to replace our original *in-water* film dosimetry approach [2], enabling faster and more reliable QA.
- This work reports a five-year assessment of the reliability of the new *in-air* film dosimetry approach.

METHODS AND MATERIALS

- GAFChromic EBT3 film was sandwiched between the plates of a custom two-piece Lexan cassette (as shown in Figure 1) containing seven dose-measurement regions; one central (C) and six off-center: 2.5 cm lateral (B, D), 5 cm lateral (A, E), and 8 cm above/below center (F, G).
- The cassette was placed vertically inside the Cs-137 irradiator canister.
- One set of films was irradiated to ~8 Gy with the canister filled with water (standard *in-water* measurement), a second set was irradiated to the same dose with the canister empty (*in-air* measurement).
- After scanning the films using Epson Expression 10000XL scanner 24 hrs after irradiation, the optical density was converted to dose using the established calibration curve.
- Comparing *in-water* and *in-air* doses at each region yielded *air-to-water* conversion factors (Table 1), applied to convert subsequent *in-air* measured data to equivalent *in-water* doses.
- This *in-air* approach was applied for routine periodic QA from 2021-2025.
- Results were compared against manufacturer specified relative doses and against independent *in-water* dose-mapping data from two commercial vendors.

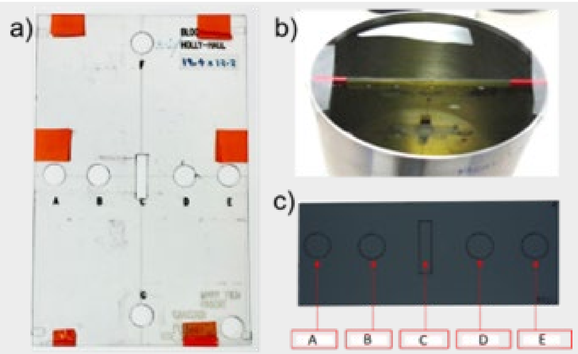

Figure 1: (a) The film cassette system showing different dose measurement regions, (b) The film-cassette system placed diametrically vertically in the canister (Only water filled canister is shown). Exact same orientation of the films was also used in *in-air* measurements. Diametric positioning of the film-cassette system was maintained during the canister rotation by two pieces of tape as shown, and (c) The central-portion of the exposed film shows rectangular and circular markings for dose measurement regions (top and bottom regions not shown)

RESULTS

- Air-to-water dose conversion factors, derived from paired *in-water*/*in-air* film measurements, are summarized in Table 1 (and shown in Figure 2): 0.68 (Center), 0.69 (2.5 cm lateral), 0.77 (5 cm lateral), 0.64 (8 cm above), and 0.65 (8 cm below).
- Applying these factors to five years of *in-air* measurements (2021-2025) produced consistent *in-water*-equivalent dose estimates in each region with minimal year-to-year fluctuation (Figure 3).
- The five-year average central dose, normalized to the manufacturer-specified value, was approximately 99% or within 1% of the reference.
- Off-center relative doses agreed with manufacturer-provided and independent commercial dose-mapping values within approximately 3% over the past five years.

Table 1. Air-to-Water dose conversion factor by region

Region	Location	Distance from Center	Air-to-Water factor
C	Center	0 cm	0.68
B, D	Lateral	2.5 cm	0.69
A, E	Lateral	5 cm	0.77
F	Above	8 cm	0.64
G	Below	8 cm	0.65

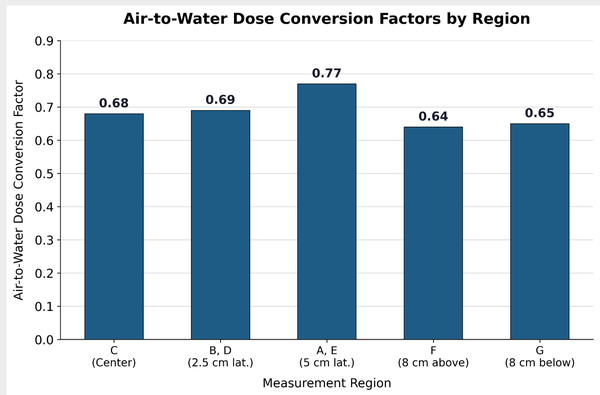

Figure 2: The bar plot showing air-to-water conversion factors by region

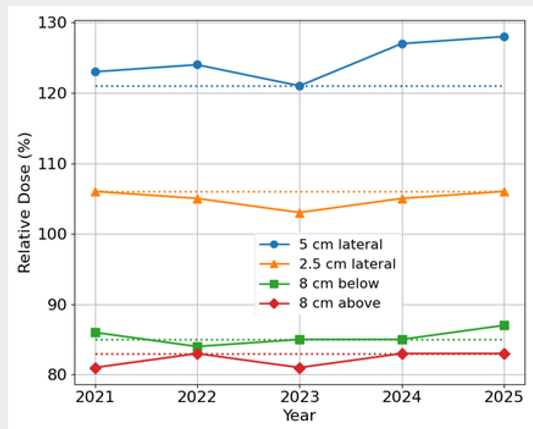

Figure 3: Five-year trend of the measured data (based on conversion of *in-air* measured data to *in-water* data) for off-axis points. Horizontal dotted lines indicate the manufacturer-provided relative %doses at the given off-axis points. While not shown in this plot, the five-year average relative dose at the center, normalized to the manufacturer-stated absolute dose, was ~ 99%.

DISCUSSION

- The results accumulated over the past five years suggest that the *in-air* film dosimetry approach provides a reliable and consistent alternative to conventional *in-water* measurements for periodic QA of Cs-137 blood irradiators.
- Agreement with both manufacturer-specified values and independent *in-water* measurements from two commercial dose-mapping providers held steady from 2021 through 2025, with no systematic drift at any of the seven measurement regions.
- Beyond dosimetric accuracy, the *in-air* approach removes the most common sources of workflow disruption in water-based QA: accidental spills and water leaks from canisters weakened by years of structural wear and tear.
- Measurements are faster and easier to perform, and less prone to the unexpected delays that *in-water* methods can introduce.
- Because the *air-to-water* conversion factors were derived once and applied consistently over all five years, the current dataset also serves as a practical validation of the dose conversion approach under the given irradiation geometry with Cs-137.
- The consistency observed suggests the approach should generalize well to other Cs-137 blood irradiators of the same model.
- By eliminating water-handling steps, the current *in-air* film dosimetry approach likely also reduces operator-to-operator variability in QA measurements, ensuring more uniform QA results among the operators performing periodic QA of Cs-137 blood irradiators.

CONCLUSIONS

- The *in-air* film dosimetry approach showed consistently good agreement with reference data over the past five years, at both the central and off-axis measurement regions.
- This confirms the effectiveness and robustness of the approach for routine periodic QA of Cs-137 blood irradiators, and supports its continued use as a simpler, faster, and more hassle-free replacement for a conventional approach based on *in-water* film dosimetry measurements.
- Future work may extend this validation to additional Cs-137 irradiator models and quantify other benefits (e.g., time saving) from eliminating a water-based film dosimetry setup.

REFERENCES

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