Feasibility Study of Using HDR1000+ Well-Type Ionization Chambers for Solution Based ^{90}Y Measurements

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ABSTRACT

Purpose: 90Y is a challenging radionuclide to measure because it is a pure beta-emitter and is typically quantified using a radionuclide calibrator. These devices, such as the Capintec model used in this study, rely on Bremsstrahlung radiation, and are inefficient for pure beta-emission measurement. This study aimed to evaluate whether an air-communicating well-type ionization chamber could serve as an alternative for measuring the signal from 90Y solutions.

Methods: A Capintec 55tR radionuclide calibrator was used to establish a baseline for activity determinations. Multiple HDR1000+ well chambers were tested, including aluminum- and custom C552-walled designed to minimize beta attenuation. A 90Y solution, calibrated at NIST, with an initial activity of 177.7 MBq was measured in syringe and 10R vial geometries. Volume effects were assessed by varying syringe volumes, and additional measurements were taken with aluminum shielding to fully attenuate beta particles. Calibration coefficients [MBq/pA] were determined for each chamber.

Results: All chambers detected signals from the 90Y source with acceptable signal-to-noise ratios. We measured very similar signals in both the aluminum- and C552-walled chambers. With additional aluminum in the standard HDR1000+, the signal measured dropped to nearly zero. Assuming a minimum detectable signal of 1 pA, the minimum detectable activity (MDA) in the aluminum-walled chamber was 2.78 MBq for the 10R vial and 0.68 MBq for the syringe. The MDA in the C552-walled chamber was 2.95 MBq for the 10R vial and 0.63 MBq for the syringe.

Conclusions: The chamber wall material does not significantly impact the detected signal, and ionization currents primarily result from beta particles rather than Bremsstrahlung radiation. The strong SNR for 90Y measurements suggests that well chambers could be viable tools for a wide range of difficult-to-measure radionuclides. The low MDA also indicates viability, as clinical 90Y solution has typical activity on the order of GBq.

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INTRODUCTION

Air-communicating, well-type ionization chambers are the standard for brachytherapy applications and are commonly available in clinics, but their application to solution-based radionuclides used in nuclear medicine and radiopharmaceutical therapy has not been investigated. This study explored the novel use of such chambers for measuring solution-based radionuclides

Radionuclide calibrators remain the standard for such measurements in the clinic, despite their low detection efficiency for radionuclides like 90Y. For such radionuclides, they rely on Bremsstrahlung radiation for signal detection, and do not directly measure the beta emissions.

This study evaluates well chambers as a viable alternative and demonstrates their potential to provide higher efficiency and improved performance for measuring challenging radionuclides.

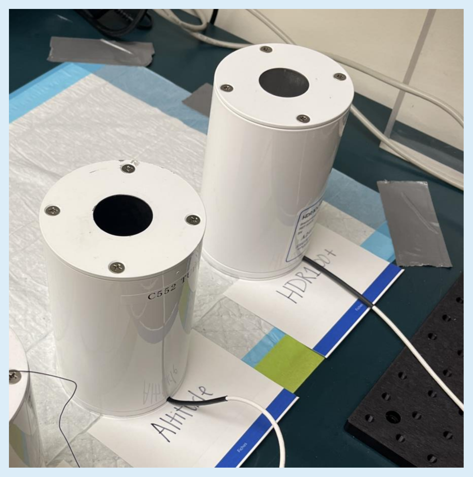


Figure 1. Well chambers used in study.

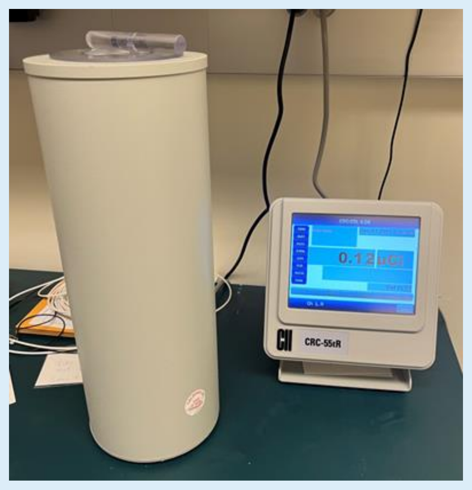


Figure 2. Capintec 55tR radionuclide calibrator.

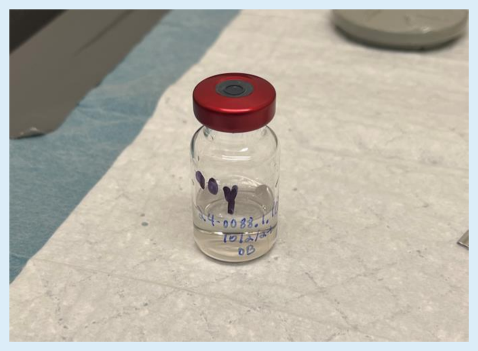


Figure 3. 10R vial geometry.

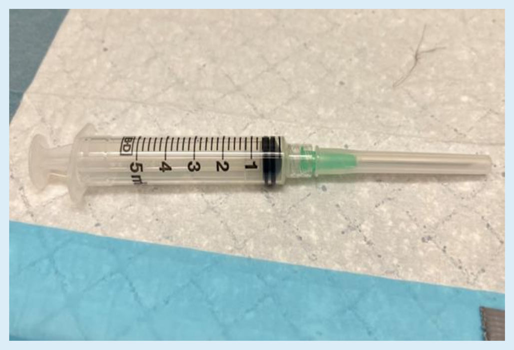


Figure 4. Syringe geometry.

METHODS AND MATERIALS

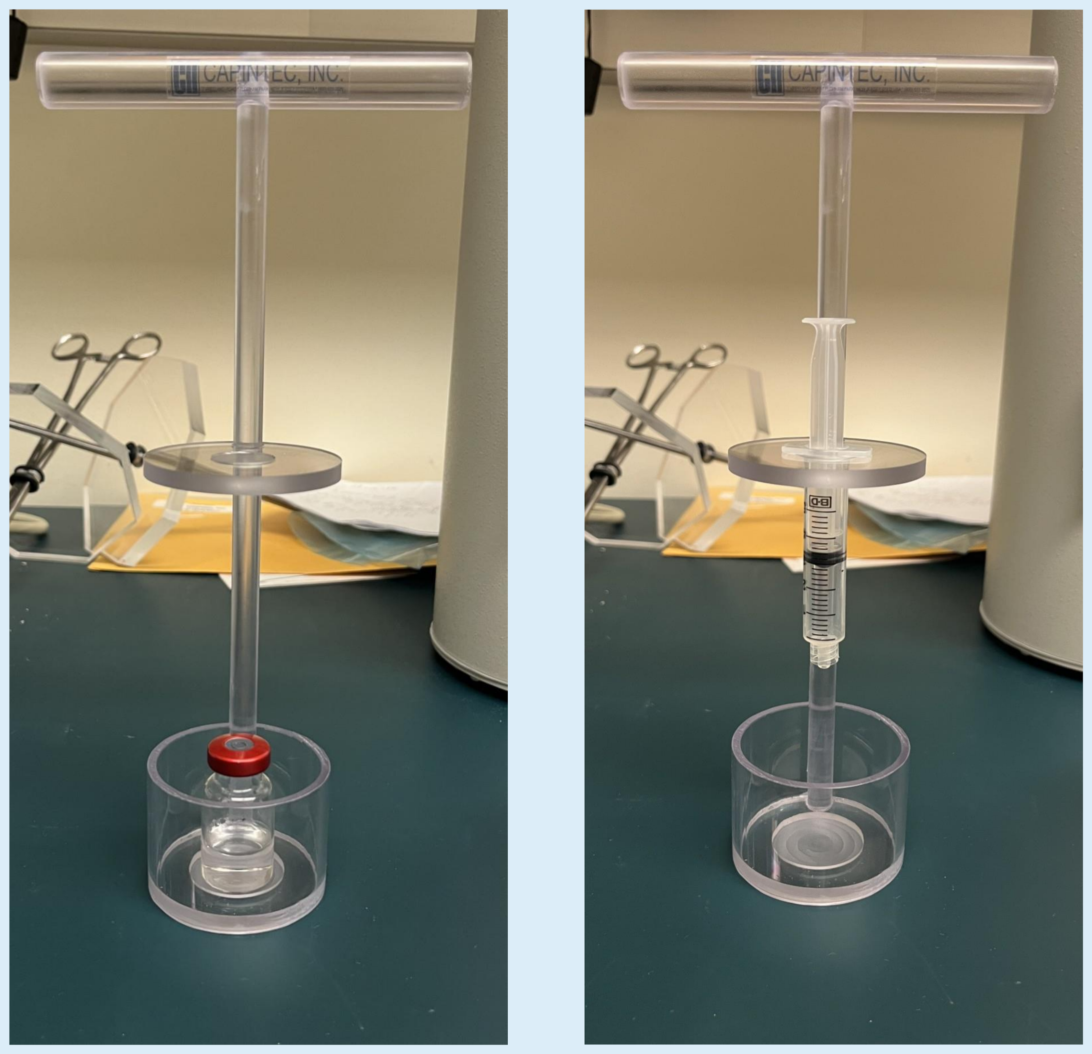
For this study, we employed the use of the following:

- Standard Imaging HDR1000+ Well Chamber
- Custom C552 Insert Standard Imaging Well Chamber
- Standard Imaging MAX4000 Electrometer
- Capintec 55tR Radionuclide Calibrator

The 90Y source used was a 5 mL source of 90Y in dilute HCl in a 10R vial. This source was provided by the Radioactivity Group at NIST and had an activity of 177.7 MBq. For the geometry study, we also employed the use of a 5 mL luer-lock syringe.

To do this study, we took 10, 1-minute charge readings of the signal from the source in each of the geometries. These signals were background- and decay-corrected.

To study whether the source of the signal was directly due to beta emissions or secondary Bremsstrahlung radiation, a 3.5mm thick aluminum cuff was placed inside the HDR1000+. This cuff in addition to the thickness of aluminum comprising the inner wall of the chamber was thick enough to block all the beta particles coming from the source.



Figures 5 and 6. 10R vial (left) and syringe (right) geometries held inside the Capintec 55tR dipper. Can see the large difference in where the two geometries sit in the chamber.

RESULTS

All chambers detected signals from the 90Y source with acceptable signal-to-noise ratios.

We measured very similar signals in both the aluminum- and C552-walled chambers.

With additional aluminum in the standard HDR1000+, the signal measured dropped to nearly zero.

Assuming a minimum detectable signal of 1 pA, the minimum detectable activity (MDA) in the aluminum-walled chamber was 2.78 MBq for the 10R vial and 0.68 MBq for the syringe. The MDA in the C552-walled chamber was 2.95 MBq for the 10R vial and 0.63 MBq for the syringe.

Chamber Wall	Source Geometry	Decay Corrected Avg Current [pA] (to 11:00 CT)	Current per Activity [pA/Mbq]
Aluminum	10R Vial	-63.8089	-0.36
	5 mL Syringe	-173.5692	-1.59
HDR1000+ with 3.5 mm Al	10R Vial	-1.9086	-0.01
	5 mL Syringe	-2.0329	-0.02
C552	10R Vial	-60.3532	-0.35
	5 mL Syringe	-173.4142	-1.60

Table 1. Results of measurements in all both well chambers for both the 10R vial and syringe geometry.

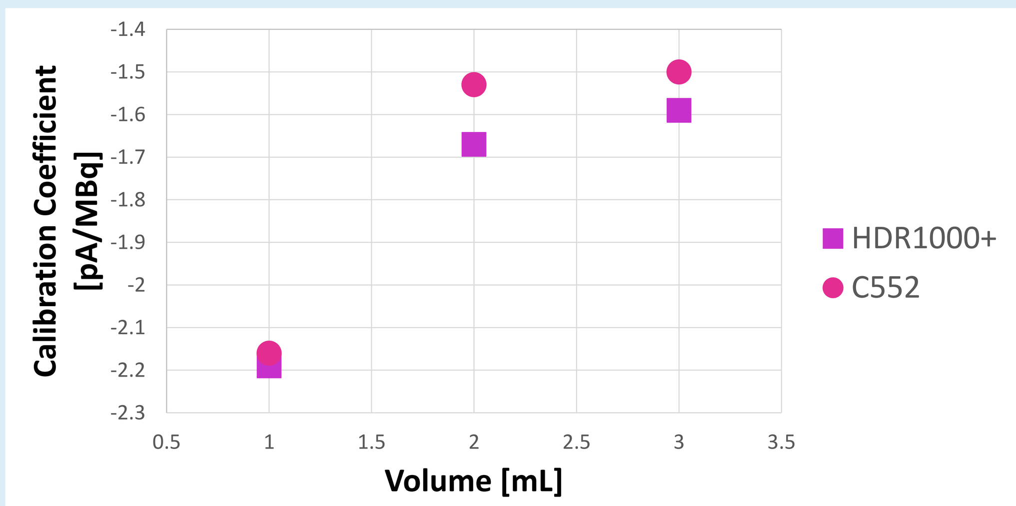


Chart 1. Comparison of the results for the volume study between the two chambers.

DISCUSSION

We demonstrated that ionization currents from solution-based 90Y could be measured with acceptable signal-to-noise ratios across multiple geometries and volumes in both aluminum- and C552-walled well chambers.

Our findings indicate that the detected signal is primarily due to direct interactions with the beta-particles emitted from the source rather than secondary Bremsstrahlung radiation produced in the chamber walls.

The signals measured with aluminum and C552 walls were consistently similar, suggesting that material composition of the chamber has minimal impact on measurement accuracy. This contrasts with radionuclide calibrators, which are more dependent on Bremsstrahlung production and wall material for signal detection.

Solution-based 90Y used in clinical treatment has activity on the order of GBq, three orders of magnitude higher than the observed MDA, meaning clinically relevant activity levels can be easily detected in these chambers

CONCLUSIONS

From this study, we conclude that well-type ionization chambers are suitable for the measurement of solution-based radionuclides, and they are able to directly detect beta emissions instead of relying on Bremsstrahlung production in the walls of the chamber.

These results underscore the potential of well chambers as a reliable and efficient alternative for measuring solution-based radionuclides.

Future work will include another round of 90Y measurements as part of a study to use well-type ionization chambers as a transfer instrument for absolute activity determinations. Additionally, future studies will be conducted with different radionuclides that produce different emissions, and more studies on the effect of geometry on the signal seen in the chamber.

REFERENCES

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