Challenges in migrating $^{90}$Y calibrations to new ionization chambers: geometry, height, and impurity effects.

Denis E. Bergeron, Jeffrey T. Cessna, and Brian E. Zimmerman
NIST, Gaithersburg, MD 20899, USA

Objective: Yttrium-90 microspheres are used for targeted radiotherapy in patients with liver cancer. Activity measurements of irradiated glass microspheres are traceable to a standard developed at the National Institute of Standards and Technology (NIST) in 1991. The very small pair-production branch in $^{90}$Y decay allows (potentially quantitative) imaging by positron emission tomography (PET). We have recently achieved a PET recovery coefficient of $0.93 \pm 0.02$ with a uniform phantom filled with $^{90}$YCl, where the main uncertainty contributions came from the uncertainty on the pair production branching ratio and from the dose calibrator activity assay; the uncertainty on calibration of the PET scanner is not included. In 2014, it was deemed necessary to transfer the NIST standard for $^{90}$Y glass microspheres from one aging ionization chamber (dose calibrator) to several others, resulting in a possible bias and increased uncertainty. In this work, we show that quantitation of $^{90}$Y microsphere PET images will be limited in both accuracy and precision by the dose calibrator measurements. Methods: Two vials containing $^{90}$Y microspheres were measured on a dose calibrator for which geometry-specific (with and without hand-shield) dial settings were established as part of the 1991 standardization. The calibration curve method was then applied with four other chambers to determine new calibration factors. Results: The initial assays revealed an $\approx 4\%$ difference between the activities determined with and without the hand-shield. It appears that a change in the source geometry between 1991 and 2014 introduced a systematic bias that must now be treated as a source of uncertainty. Calibration factors were determined for three of the four chambers, with total combined uncertainties $\approx 4\%$ mostly due to the uncertainty on the initial assay. The fourth chamber suffered from a $>8\%$ activity-dependent bias. Height and impurity effects were studied in detail, offering plausible explanations for the observed bias. Conclusions: NIST calibrations for $^{90}$Y glass microspheres have been transferred to several newer ionization chambers. The transfer identified a significant source of uncertainty in the measurements, which could be resolved by new primary measurements and new determinations of geometry-specific calibration factors. If the goal is to know the activity to better than $10\%$, then the present standards suffice. But if image quantitation is limited by the precision of the activity assay, then the drive towards patient-specific image-guided dosimetry may also drive a need for an improved standard with the $\approx 1\%$ uncertainties more typical of NIST activity calibrations.