CCRI(I)/01-15

Update on NIST Brachytherapy Standards and Calibrations

Paul Lamperti, Michael Mitch, Christopher Soares and Stephen Seltzer
Ionizing Radiation Division
National Institute of Standards and Technology
Gaithersburg, MD 20899 USA

April 5, 2001

NIST continues in its active program of brachytherapy measurements. The work falls mainly into two application areas that have experienced vigorous growth and interest: the treatment of prostate cancer by radiation seed implants, and the inhibition of restenosis following balloon angioplasty by catheter-based radiation sources.

1. Prostate seeds

Seeds are calibrated using the Wide-Angle Free-Air Chamber (WAFAC), established as the national standard in 1999 for reference air-kerma rate for low-energy photon-emitting brachytherapy sources, and replacing the earlier measurements of Loftus using the Ritz FAC. NIST uses two WAFACs, the original Loevinger model, and a more recent automated, variable-volume model. The WAFAC has the following characteristics: (1) The aperture has a diameter of up to 8 cm, and is placed at a distance of nominally 30 cm from the source. This allows the measurement of radiation in the cone with a half-angle of up to approximately 8°, rather than the ~1° for the Ritz FAC measurements, for an advantage by a factor of more than 40 in solid angle. Hence the wide-angle description. (2) The effective or defined volume is ~704 cm^3, and the collecting volume is ~2474 cm^3, rather than ~5.5 cm^3 and 567 cm^3, respectively, for the Ritz FAC. The larger effective volume makes the WAFAC about 100 times more sensitive than the Ritz FAC. Moreover, the ratio of effective to collecting volumes is about 0.28 for the WAFAC compared to only about 0.01 for the Ritz FAC, giving a much improved signal-to-background ratio.

We find somewhat of a conceptual problem with the WAFAC measurements. A correction (1.0089 for the aperture at 30 cm from the seed axis) is made to relate the measured air-kerma rate averaged over the 4 cm radius aperture to that at a point at the center, but assuming the radiation is from a point source. The internal structure of the seed can be such that angular distribution of the radiation, even at this distance, might vary significantly from that of a point source, and this variation might be different from seed to seed of the same design. This does not vitiate the WAFAC result as a useful calibration quantity: the measurement geometry is stated in the calibration report, and the

result can be considered an average over the ~8° cone (multiplied by 1.0089). However, one might anticipate discrepancies with measurements done in a different geometry.

All measurements are done with a 0.0233 g/cm^2 Al filter to effectively eliminate the contribution from Ti characteristic x rays produced in the Ti encapsulation. For routine measurements, the seed is rotated about its axis to average over any axial non-uniformity. A relative measurement with the WAFAC of axial non-uniformity is made of each seed orientated at 45º intervals about its long axis. For one seed in each submitted batch, one of the replicate calibration measurement series is done with the original WAFAC to ensure consistency (agreement between the two chambers is typically better than 0.2%). One seed in each submitted batch is measured (rotating) using a HPGe spectrometer with a 5 mm diameter W aperture, mainly to monitor the emitted photon spectrum, but also for possible conversion of the absolute emitted fluence rate to air-kerma rate. An ^{241}Am source is measured with both WAFACs one or more times per month as a quality-control measure, demonstrating a long-term stability of ~0.3%. All seeds are also measured with three or four well-ionization chambers to monitor for consistent responses. So far, calibrations have been provided for seeds of some 18 models from 13 manufacturers, listed in Table 1.

Table 1. Low-energy photon-emitting brachytherapy seeds with US calibrations.

Isotope	**Manufacturer**	**Distributor**	**Seed Model**
^{125}I	Nycomed-Amersham	Nycomed-Amersham	6702
^{125}I on Ag	Nycomed-Amersham	Nycomed-Amersham	OncoSeed (6711)
^{103}Pd	Theragenics	Indigo Medical (J&J)	TheraSeed 200
^{125}I	North American Scientific	Mentor	IoGold (MED3631-A/M)
^{103}Pd	North American Scientific	Mentor	PdGold (MED3633)
^{125}I on Ag	International Isotopes Inc.	Imagyn	IsoSTAR (IS-12500,IS-12501)
^{103}Pd	International Brachytherapy	IBt	InterSource^{103}
^{125}I	International Brachytherapy	IBt	InterSource^{125}
^{125}I on Pd	Syncor	Syncor	PharmaSeed I-125
^{125}I	Bebig	UroMed	Symmetra I-125 (IsoSeed I25.S06)
^{103}Pd	Bebig	(NA)	(IsoSeed Pd3.S11)
^{125}I	Eurotope	(NA)	(I25.S12)
^{125}I	Best Medical International	Best	Best Iodine-125 (2301)
^{103}Pd	Best Medical International	Best	Best Palladium-103 (2335)
^{125}I on Ag	DraxImage	Cytogen	BrachySeed
^{125}I	Implant Sciences	Implant Sciences	I-Plant
^{125}I on Ag	Mills Biopharmaceuticals	UroCor	ProstaSeed I-125 (125SH)
^{125}I	SourceTech Medical	SourceTech	STM1251

2. Intravascular sources

Techniques for source calibration and uniformity characterization have been developed employing a variety of measurement systems. A reference value of the absorbed-dose rate to water at a 2 mm depth in water-equivalent plastic is determined with the NIST extrapolation chamber equipped with a 1 mm diameter collecting electrode. Calibrated radiochromic-dye film, read out with an imaging densitometer is used both to confirm the

extrapolation-chamber measurement and to provide information on the spatial distribution of absorbed-dose rate around the source. In many measurements for a well-characterized source design, calibrated radiochromic-dye film is used exclusively as the dosimeter. The source is also measured in well-ionization chambers both to transfer the absorbed-dose-rate calibration to the chamber that can be used in subsequent calibrations of sources of the same design and to check consistency with the film measurements. So far, measurements have been provided for the sources listed in Table 2, for source lengths from 20 to 40 mm.

Table 2. Intravascular brachytherapy sources with NIST measurements.

Isotope	**Source Type**	**Manufacturer**	**Model**
$^{90}Sr/^{90}Y$	seed train	Novoste Corporation	Beta-Cath System
^{32}P	wire	Guidant Corporation	GALILEO System
^{32}P	balloon surface	Radiance Medical Systems	RDX Catheter
$^{188}W/^{188}Re$	wire	Best Medical Intemational	-
^{192}Ir	seeds	Best Medical International	-
^{125}I	wire	Cordis Corporation (J&J)	-

Studies of extrapolation-chamber measurements with smaller air gaps indicated a more linear extrapolation region that resulted in a +15 % change for the Novoste $^{90}Sr/^{90}Y$ source calibrations. Values of reference absorbed-dose rate for sources with measured source activities then agreed more closely with those from theoretical modeling. A new, small-area collecting electrode is now under development that should lead to a reduction of uncertainties in the extrapolation-chamber measurements.