A photon spectrometric dose-rate constant determination for the Advantage™ Pd-103 brachytherapy source

Zhe Jay Chen,^{a)} Paul Bongiorno, and Ravinder Nath

Department of Therapeutic Radiology, Yale University School of Medicine, New Haven, Connecticut 06520

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Purpose: Although several dosimetric characterizations using Monte Carlo simulation and thermoluminescent dosimetry (TLD) have been reported for the new Advantage™ Pd-103 source (IsoAid, LLC, Port Richey, FL), no AAPM consensus value has been established for the dosimetric parameters of the source. The aim of this work was to perform an additional dose-rate constant (Λ) determination using a recently established photon spectrometry technique (PST) that is independent of the published TLD and Monte Carlo techniques.

Methods: Three Model IAPD-103A Advantage™ Pd-103 sources were used in this study. The relative photon energy spectrum emitted by each source along the transverse axis was measured using a high-resolution germanium spectrometer designed for low-energy photons. For each source, the dose-rate constant was determined from its emitted energy spectrum. The PST-determined dose-rate constant ($_{\text{PST}}\Lambda$) was then compared to those determined by TLD ($_{\text{TLD}}\Lambda$) and Monte Carlo ($_{\text{MC}}\Lambda$) techniques. A likely consensus Λ value was estimated as the arithmetic mean of the average Λ values determined by each of three different techniques.

Results: The average $_{\text{PST}}\Lambda$ value for the three Advantage™ sources was found to be (0.676 ± 0.026) $\text{cGy h}^{-1} \text{U}^{-1}$. Intersource variation in $_{\text{PST}}\Lambda$ was less than 0.01%. The $_{\text{PST}}\Lambda$ was within 2% of the reported $_{\text{MC}}\Lambda$ values determined by PTRAN, EGSnrc, and MCNP5 codes. It was 3.4% lower than the reported $_{\text{TLD}}\Lambda$. A likely consensus Λ value was estimated to be (0.688 ± 0.026) $\text{cGy h}^{-1} \text{U}^{-1}$, similar to the AAPM consensus values recommended currently for the Theragenics (Buford, GA) Model 200 (0.686 ± 0.033) $\text{cGy h}^{-1} \text{U}^{-1}$, the NASI (Chatsworth, CA) Model MED3633 (0.688 ± 0.033) $\text{cGy h}^{-1} \text{U}^{-1}$, and the Best Medical (Springfield, VA) Model 2335 (0.685 ± 0.033) $\text{cGy h}^{-1} \text{U}^{-1}$ ^{103}Pd sources.

Conclusions: An independent Λ determination has been performed for the Advantage™ Pd-103 source. The $_{\text{PST}}\Lambda$ obtained in this work provides additional information needed for establishing a more accurate consensus Λ value for the Advantage™ Pd-103 source. © 2010 American Association of Physicists in Medicine. [DOI: [10.1118/1.3298011](https://doi.org/10.1118/1.3298011)]

Key words: dose-rate constant, palladium-103, photon energy spectrum, interstitial brachytherapy

I. INTRODUCTION

In 2004, IsoAid, LLC received approval from the U.S. Food and Drug Administration to market a newly designed Advantage™ Pd-103 source for interstitial prostate brachytherapy. The dosimetric parameters of this source have been characterized recently by several groups using thermoluminescent dosimetry (TLD) and Monte Carlo simulations.^{1–4} However, no AAPM consensus value for these dosimetric parameters have been established for clinical dosimetry. In this technical note, we report an additional determination of the dose-rate constant (Λ) for this source by using a recently established photon spectrometry technique⁵ (PST) that is independent of the TLD and Monte Carlo techniques used previously.⁶ Because the PST technique has helped to uncover a 15% discrepancy in the Λ determined initially for a ^{131}Cs source and the PST-determined Λ values were shown to agree closely with the AAPM consensus values for several source models that have such a value,⁵ the addition of a Λ value determined by this technique would help to establish a more accurate consensus Λ value for this source model.

II. METHOD AND MATERIALS

Three Model IAPD-103A Advantage™ Pd-103 sources were obtained from IsoAid, LLC. Each source consisted of a 1.25 mm long and 0.5 mm diameter cylindrical silver marker flanked by two carbon matrix spheres on each side.^{1,3} Palladium-103 is distributed uniformly on the four carbon matrix spheres. These components are encapsulated in a titanium tube with an overall length of 4.5 mm, an outer diameter of 0.8 mm, and a wall thickness of 0.05 mm.^{1,3}

The photon energy spectrum emitted by each source along the transverse axis was measured in air using a high-resolution intrinsic germanium spectrometer established in our laboratory for low energy, photon-emitting brachytherapy sources.⁵ The calibration and validation of the spectrometry system and its use in the determination of dose-rate constants for brachytherapy sources have been described in detail by Chen and Nath,⁵ which will not be reproduced here. Because the photon spectrometry technique utilizes both experimentally measured energy spectrum and Monte Carlo calculated dose-rate constant of monoenergetic photons, it

TABLE I. Relative photon energy spectrum.

Lavel	Energy (keV)	Relative Energy Spectrum	
		Bare source ^a	Advantage (Model IAPD-103A)
X ray	K_{α}	20.1	1
X ray	K_{β}	22.9	0.185 ± 0.011
Gamma	39.7	0.001 ± 0.002	0.002 ± 0.0
Gamma	>39.7	<0.001	<0.001

^aInformation extracted from the NuDat database (<http://www.nndc.bnl.gov/nudat2>) version 2/6/2007, maintained by Brookhaven National Laboratory. The uncertainty for the relative spectrum was estimated from the uncertainties reported for individual photon emission modes following the standard uncertainty propagation rules.

was considered as an independent technique in the estimation of a likely consensus Λ value. Specifically, a likely consensus Λ was estimated as the arithmetic mean of the average Λ values determined by each of the three techniques, i.e., $[\langle\Lambda_{\text{TLD}}\rangle + \langle\Lambda_{\text{MC}}\rangle + \langle\Lambda_{\text{PST}}\rangle]/3$.

III. RESULTS AND DISCUSSION

Table I summarizes the measured relative energy spectrum for the AdvantageTM Pd-103 source and the theoretical spectrum of bare ^{103}Pd derived from the NuDat database.⁸ The relative spectra were obtained by normalizing each spectrum with their respective K_{α} spectral intensity. The uncertainties for the measured energy spectra were estimated according to the method described in detail in Ref. 5, which included both the uncertainties of the spectrometry system and the standard deviation among the three AdvantageTM Pd-103 sources included in this study. As expected, the spectrum emitted by the AdvantageTM source was hardened by the titanium encapsulation compared to that emitted by the bare ^{103}Pd .

Table II compares the PST-determined dose-rate constant with those reported previously for the AdvantageTM Pd-103 source. Intersource variation in Λ_{PST} was found to be less than 0.01%. The mean Λ_{PST} obtained from the three sources included in this study was $(0.676 \pm 0.026) \text{ cGyh}^{-1} \text{ U}^{-1}$. This value was within 2% of the Λ_{MC} determined by Monte Carlo simulations using EGSnrc,² PTRAN,¹ and MCNP5 (Ref. 4)

codes. It was 4.7% lower than the Λ_{MC} determined by PTRAN using a point-source approximation.⁵ It was also 3.4% lower than the Λ_{TLD} of $(0.700 \pm 0.056) \text{ cGyh}^{-1} \text{ U}^{-1}$ determined by TLD.¹ A detailed delineation of the causes of the apparent differences in the Λ values determined by different dosimetry techniques is beyond the scope of this technical note. Interested readers are referred to the 2004 update of the AAPM TG-43 report for a discussion of the possible causes.⁷ A likely consensus Λ value was estimated to be $(0.688 \pm 0.026) \text{ cGyh}^{-1} \text{ U}^{-1}$, which is similar to the AAPM consensus values established for the Theragenics Model 200 (Ref. 7) $(0.686 \pm 0.033) \text{ cGyh}^{-1} \text{ U}^{-1}$, the NASI Model MED3633 (Ref. 7) $(0.688 \pm 0.033) \text{ cGyh}^{-1} \text{ U}^{-1}$, and the Best Medical Model 2335 (Ref. 9) $(0.685 \pm 0.033) \text{ cGyh}^{-1} \text{ U}^{-1}$ Pd-103 sources. The uncertainty associated with the likely consensus value was estimated following the methodology described in Ref. 7 as

$$\begin{aligned} \% \sigma_{\text{CON}\Lambda}^2 = & \left(\frac{1}{3} \right)^2 \left(\frac{\Lambda_{\text{TLD}}}{\Lambda_{\text{CON}}} \right)^2 \% \sigma_{\text{TLD}\Lambda}^2 \\ & + \left(\frac{1}{3} \right)^2 \left(\frac{\Lambda_{\text{MC}}}{\Lambda_{\text{CON}}} \right)^2 \% \sigma_{\text{MC}\Lambda}^2 \\ & + \left(\frac{1}{3} \right)^2 \left(\frac{\Lambda_{\text{PST}}}{\Lambda_{\text{CON}}} \right)^2 \% \sigma_{\text{PST}\Lambda}^2 + (\% \sigma_B)^2, \end{aligned} \quad (1)$$

where

$$\% \sigma_B = 100 \max |I\Lambda - J\Lambda| / (2\sqrt{3}\Lambda_{\text{CON}}). \quad (2)$$

In Eq. (2), I and J index the three different dosimetry techniques. Percent uncertainties of 8.7, 3.7, and 3.8 were used for the TLD, MC, and PST techniques, respectively, in this estimation.

IV. CONCLUSIONS

An independent determination of the dose-rate constant has been carried out for the AdvantageTM Pd-103 source using the photon spectrometry technique.⁵ The dose-rate constant obtained in this work provides additional information needed for establishing a more accurate AAPM consensus dose-rate constant value for the AdvantageTM Pd-103 source.

TABLE II. Dose-rate constants determined for the AdvantageTM Pd-103 source.

Reference	Technique	Λ ($\text{cGyh}^{-1} \text{ U}^{-1}$)	Relative difference of our work compared to other published results (%)
This work	Photon spectrometry	0.676 ± 0.026	...
Taylor and Rogers ^a	EGSnrc (WAFAC)	0.687 ± 0.002	-1.4
Meigooni <i>et al.</i> ^b	PTRAN-Extrap	0.690 ± 0.021	-2.0
Wang <i>et al.</i> ^c	MCNP5	0.671	0.7
Sowards ^d	PTRAN-Point	0.709 ± 0.014	-4.7
Meigooni <i>et al.</i> ^b	TLD	0.700 ± 0.056	-3.4
Arithmetic mean	$[\langle\Lambda_{\text{PST}}\rangle + \langle\Lambda_{\text{MC}}\rangle + \langle\Lambda_{\text{TLD}}\rangle]/3$	0.688 ± 0.026	-1.1

^aReference 2.

^bReference 1.

^cReference 4.

^dReference 3.

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^{a)}Electronic mail: zhe.chen@yale.edu

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