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Guidance to Users of Nycomed Amersham and North American Scientific, Inc. I-125 Interstitial Sources: Dosimetry and Calibration Changes

Recommendations of the American Association of Physicists in Medicine Radiation Therapy Committee Ad Hoc Subcommittee on Low-Energy Seed Dosimetry

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Abstract

Dose calculations to patients undergoing implantation of ^{125}I interstitial brachytherapy sources are affected by two recent changes in low-energy seed dosimetry: implantation of a new primary air-kerma strength standard at the National Institute of Standards and Technology (NIST) on 1 January 1999 and (b) publication of revised dose-rate distributions in AAPM's Task Group 43 Report. The guidance herein represents AAPM's recommendations for users of ^{125}I interstitial seed products marketed prior to 1 January 1999 (Nycomed Amersham models 6711 and 6702 and North American Scientific, Inc. models 3631 A/S and 3631 A/M. Implementation of Task Group 43 (TG-43) ^{125}I dose calculations involves revising data stored in files of radiation treatment planning software and lowering the prescribed dose to be delivered to patients by as much as 15% to avoid modifying the dose actually delivered to patients. The magnitude of the dose prescription change depends on the dosimetry data used prior to TG-43 and the implant geometry. Adapting to the revised NIST calibration standard requires the user to increase the dose-rate constant (or its equivalent by 11.5%) but does not require modification of the prescribed dose. Failure to correctly implement these modifications can result in 20% or even 30% errors.

Keywords: Brachytherapy, ^{125}I seeds, dosimetry, air-kerma strength, primary standard, dose-rate constant, Task Group 43

Introduction

This guidance is to alert physicists and radiation oncologists to two changes affecting calculations of dose from ^{125}I interstitial brachytherapy sources. (a) The National Institute of Standards and Technology (NIST) is implementing a new primary calibration standard for these sources on 1 January 1999. Sources marketed in 1998 will undergo a change in calibration on 1 January 1999. New source designs that become available after this date will be calibrated to the new standard. (b) In 1995, the American Association of Physicists in Medicine (AAPM) published a revised dose-calculation protocol, developed by its Task Group 43 and known as the TG43 report. Both of these changes require modification of the dosimetric constants stored in the input files of radiation treatment planning (RTP) software and may involve revising the prescribed dose. Following the protocol herein will not modify doses delivered to patients. The TG43 protocol and the revised NIST standard, implemented either singly or in combination, simply provide a more rigorous estimate of the absorbed dose that brings calculated stated doses into closer alignment with doses actually delivered to patients. Physicists should not implement these changes without consulting with the responsible radiation oncologist. Failure to modify dose-calculation procedures in response to the new calibration standard will result in dose-delivery errors, relative to past practice, of 10% while incorrect application of these factors can result in 20% or even 30% errors. This notice briefly reviews the procedure for adapting to these changes: more detail are given elsewhere[2].

Revised Low-Energy Seed Calibration Standard

On January 1, 1999 NIST will implement its revised air-kerma strength (S_K) standard for low-energy interstitial brachytherapy seeds[7]. Compared to seeds calibrated prior to this date, calibration values will numerically decrease by about 10%. The affected ^{125}I interstitial sources, which were marketed before January 1, 1999, are the model MED3631-A/M source, currently marketed by North American Scientific (NAS) Corporation, the currently unavailable model MED3631-A/S (the predecessor of model MED3631-A/M) source and the Nycomed Amersham models 6711 and 6702 sources. Up to January 1, 1999, these sources were calibrated against the prior NIST S_K standard implemented in 1985[4], Other products containing Model 6711 seeds (Models 6720 and 7000) are affected as well. To avoid confusion, air-kerma strength traceable to the 1985 and 1999 standards will be denoted by $S_{K,85std}$ and $S_{K,99std}$, respectively. Both quantities have units of $\mu Gy \cdot m^2 \cdot h^{-1}$. Although NIST will implement the new standard on 1 January 1999, immediate implementation of $S_{K,99std}$ calibrations by vendors can not be guaranteed. For seeds shipped after 1 January 1999, users should check with the vendor to identify the standard to which their calibrations are referenced.

$S_{K,85std}$ calibrations were based upon Loftus' air-kerma measurements, made using the Ritz low-energy free air chamber (FAC) which officially became the primary standard in 1985[4]. These measurements were affected by 4.5 keV titanium characteristic x-rays, the significance of which was not appreciated at the time. The net effect of these low-energy x-rays, which do not contribute to dose in water at distances beyond 1 mm, was to inflate all $S_{K,85std}$ values traceable to these measurements by about 10% relative to the penetrating component of the photon spectrum[9]. $S_{K,99std}$ calibrations are based upon measurements using Loevinger's wide-angle free-

air chamber (WAFAC) with a thin absorber to eliminate the Ti x rays[7]. For all three model seeds (6711, 6702, and 3631A/S) $S_{K,85std}$ and $S_{K,99std}$ are related by:

$$\left.\frac{S_{K,99std}}{S_{K,85std}} = 0.897\right\} \quad \text{for the same seed} \qquad (1)$$

Task Group 43 Dosimetry Revisions

In 1995, the AAPM issued its Task Group 43 (TG43) report on interstitial brachytherapy dosimetry[5]. The TG43 report included a new single-source dose-calculation formalism and recommended dosimetry constants for models 6711 and 6702 sources based upon TLD dose-rate measurements normalized to $S_{K,85std}$. Subsequently, TLD dose-rate measurements normalized to $S_{K,85std}$ were reported for the NAS model 3631A/S source[8]. Similar measurements for the MED3631-A/M source have been performed but are not yet published. In the TG43 formalism, the connection between absolute dose rate and source strength is given by the dose-rate constant, $\Lambda_{TG43,85std}$ (= dose rate in water at 1 cm/$S_{K,85std}$). $\Lambda_{TG43,85std}$ deviates (see table I) by 10%-18% from the dose-rate constant, $\Lambda_{preTG43,85std}$ derived from the most widely used dose-distribution data available prior to the TG43 report[3]. Most of this discrepancy is due to inflation of $S_{K,85std}$ by low-energy photons: the pre-TG43 dose-calculation models assume that all photons contributing to S_K also contribute to tissue-medium dose rates at distances up to several cm. In contrast, the TG-43 data are based upon dose measurements in a phantom which are not affected by the low energy photons

Table I: Dose-rate constants, Λ, for I-125 interstitial sources
(Units of $cGy \cdot h^{-1} \cdot U^{-1}$ or $cGy \cdot h^{-1}/(\mu Gy \cdot m^2 \cdot h^{-1})$)

Source Model	$\Lambda_{preTG43,85std}$	$\Lambda_{TG43,85std}$	$\Lambda_{TG43,99std}$
6711	1.039	0.88	0.98
6702	1.039	0.93	1.04
MED3631-A/S	----	0.93	1.04
MED3631-A/M	----	----†	----†

†Publication of measurements pending: contact NAS for most current estimates of TG43 dosimetry ratios.

Recommended AAPM Implementation Plan

To simplify clinical implementation of these changes, the AAPM recommended a two-stage clinical implementation plan[2]: (a) First implement the TG43 dosimetry protocol for I-125 seeds; and (b) then adopt the revised air-kerma strength standard. Implementation of TG43 dosimetry means modifying the dosimetry constants stored in the appropriate RTP input file so that the predicted dose rates per unit strength agree with the dose-rate distributions recommended by the report. Such implementation is straightforward for Radiation Treatment Planning (RTP) systems that use the TG43 dosimetric ratios to input dose distributions. Implementation is more complicated, but still achievable, for systems using older dose-calculation formalisms[2].

(a) Task Group 43 Implementation

The TG43 formalism predicts dose rates that are smaller by 10-18% than their pre-TG43 counterparts due mostly to changes in the dose-rate constant, Λ, and anisotropy constant, $\bar{\phi}_{an}$, Thus using TG43 dose calculations for clinical treatment without corresponding changes in the prescribed dose, D_{Px}, will abruptly increase doses actually delivered to patients by 10-18%. To avoid this scenario, physicists should compare the doses calculated by their pre-TG43 algorithm, $D_{preTG43,85std}$, to those calculated from the TG43 report for an identical geometry. Then, the prescribed dose, $D_{Px,TG43}$, used to determine the required source strength in conjunction with the TG43 dose distribution should be adjusted as follows:

$$D_{Px,TG43} = D_{Px,preTG43} \cdot \frac{\langle D_{TG43,85std} \rangle}{\langle D_{preTG43,85std} \rangle} \qquad (2)$$

where the brackets represent spatial averaging over the typical implant geometry. Bice[1] *et al.* have shown that for prostate implants consisting of Model 6711 seeds planned with the isotropic point-source model using the most commonly used pre-TG43 dosimetry constants ($\Lambda_{preTG43,85std}$ = 1.039 and $\bar{\phi}_{an}$ = 0.87)[3] and the corresponding TG43 values ($\Lambda_{TG43,85std}$ = 0.88 and $\bar{\phi}_{an}$ = 0.93), the prescribed dose correction factor is

$$\frac{\langle D_{TG43,85std} \rangle}{\langle D_{preTG43,85std} \rangle} = 0.906 \approx \frac{(\Lambda \cdot \bar{\phi}_{an})_{TG43,85std}}{(\Lambda \cdot \bar{\phi}_{an})_{preTG43,85std}} \qquad (3)$$

independently of the detailed averaging procedure. In this example, the typical prescribed dose of 160 Gy for definitive treatment of prostate cancer by permanent I-125 seed implant alone should be lowered to 144 Gy. Although equation (3) represents a common scenario, it is essential that each institution base their dose prescription adjustment on a comparison of their own pre-TG43 dose calculations to the appropriate TG43 implementation. Readers are warned that the appropriate dose prescription factor for their clinical application depends on the dose calculation model and dosimetry constants historically used in their practices, the seed model, and the implant geometry. The example described above is not valid for all implant types and dose-calculation models. Failure to adjust the prescribed dose upon adopting the TG43 dosimetry calculations will result in an unintended increase in dose delivered to the patient as large as 18%. Adjusting the prescribed dose in accord with equation (2) will not change doses actually delivered to patients, but will eliminate differences between calculated dose and dose actually delivered to the patient relative to TG43 calculations.

To reduce the possibility of errors or misunderstandings, physicists should not implement revised dose prescription guidelines nor implement TG43 dose calculations without consulting with the responsible radiation oncologist. The revised dose calculations should be verified and all involved staff trained prior to treating patients with the new protocol. Implementation of dose calculations numerically equivalent to TG43 recommendations on RTP systems not supporting the TG43 formalism is discussed in reference 2.

(b) Adapting to the 1999 NIST standard, $S_{K,99std}$ following TG43 implementation

For all patients treated with I-125 seeds specified in terms of air-kerma strength traceable to the 1999 NIST standard, the dose-rate constant used by the treatment planning system should be updated to the value $\Lambda_{TG43,99std}$ given in table I. This modification will not change the dose delivered to the patient because the source strength values entered into the planning system will be correspondingly lower than those used with the 1985 standard. No revision of the prescribed or stated dose is necessary. Failure to revise the dose-rate constant appropriately will result in erroneous dose delivery. Following the dose-rate constant update but before treating patients, a physicist should verify that this change uniformly increases dose rates predicted by the treatment planning system by 11.5% for implants with numerically identical S_K values before and after the revision. This recommendation applies only to the Models 6711, 6702, MED3631-A/S and MED3631-A/M seeds: recommended dosimetry constants for new interstitial products entering the market after 1 January 1999 will already be normalized to the new source-strength standard. However, for the MED3631-A/M seed, additional dose-rate measurements will soon be available for review. Users of this product may want to consider adopting updated TG43 dosimetric ratios at the same time they adopt the revised NIST air-kerma strength standard. The vendor, North American Scientific, should be contacted for further information.

Adapting to the 1999 NIST standard, $S_{K,99std}$ without adopting the TG43 Report Recommendations.

If the TG43 dosimetry recommendations (or their numerical equivalents in older dose-calculation formalisms) have not been adapted, it is still necessary to modify the constants used by the treatment planning system because of the new 1999 NIST standard. Failure to make the recommended changes will result in an unintended 11.5% increase in doses delivered to patients. The pre-TG43 dose-rate constant should be modified as follows:

$$\Lambda_{pre-TG43,99std} = \Lambda_{pre-TG43,85std} \cdot \left(\frac{S_{K,85std}}{S_{K,99std}} \right) = \Lambda_{pre-TG43,85std} \cdot 1.115 \quad (4)$$

Implementation of (4) will not require adjustment of the prescribed or stated dose and will not modify doses actually delivered to patients. However, the discrepancy between the institution's calculated doses and doses as determined by the TG43 recommendations will remain unchanged.

Modification of Source-Strength Verification Procedures

With the revision of the air-kerma strength standard, corresponding adjustments must be made to the calibration factors used with dose calibrators or other re-entrant ionization chambers to verify vendor calibrations. To verify seed calibrations traceable to the new standard, multiplicative calibration factors, $N_{Sk,85std}$, used to convert instrument readings into source strengths, $S_{K,85std}$, should be modified as follows:

$$N_{Sk,99std} = N_{Sk,85std} \cdot 0.897 \quad (5)$$

The product of the instrument reading, the revised factor $N_{Sk,99std}$, and other corrections independent of the calibration standard (e.g., temperature-pressure corrections), will now represent source strength, $S_{K,99std}$, traceable to the revised standard. This recommendation applies to all seeds marketed before January 1, 1999, including model MED3631-A/M. Calibration factors traceable to the new I-125 standard will be available from the Accredited Dosimetry and Calibration Laboratories. Further guidance in implementing procedures for source-strength verification is given in reference 6.

Whom to Contact For Further Assistance

If you have questions on implementing the TG43 dosimetry recommendations or adapting to the revised source strength standard, please contact the Radiological Physics Center (RPC) at MD Anderson Cancer Center, Houston, TX at (713)-792-3233.

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