

Assaying multiple ^{125}I seeds with the well-ionization chamber SourceCheck $^{4\pi}$ 33005 and a new insert

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Abstract

Purpose: To provide a practical solution that can be adopted in clinical routine to fulfill the AAPM-ESTRO recommendations regarding quality assurance of seeds used in prostate permanent brachytherapy. The aim is to design a new insert for the well-ionization chamber SourceCheck $^{4\pi}$ 33005 (PTW, Germany) that allows evaluating the mean air-kerma strength of up to ten ^{125}I seeds with one single measurement instead of measuring each seed individually.

Material and methods: The material required is: a) the SourceCheck $^{4\pi}$ 33005 well-ionization chamber provided with a PTW insert to measure the air-kerma strength S_K of one single seed at a time; b) a newly designed insert that accommodates ten seeds in one column, which allows measuring the mean S_K of the ten seeds in one single measurement; and c) a container with ten seeds from the same batch and class of the seeds used for the patient implant, and a set of nine non-radioactive seeds. The new insert is characterized by determining its calibration coefficient, used to convert the reading of the well-chamber when ten seeds are measured to their mean S_K . The proposed method is validated by comparing the mean S_K of the ten seeds obtained from the new insert with the individual measurement of S_K of each seed, evaluated with the PTW insert.

Results: The ratio between the calibration coefficient of the new insert and the calibration coefficient of the PTW insert for the SourceCheck $^{4\pi}$ 33005 is 1.135 ± 0.007 ($k = 1$). The mean S_K of a set of ten seeds evaluated with this new system is in agreement with the mean value obtained from measuring independently the S_K of each seed.

Conclusions: The new insert and procedure allow evaluating the mean S_K of ten seeds prior to the implant in a single measurement. The method is faster and more efficient from radiation protection point of view than measuring the individual S_K of each seed.

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Key words: brachytherapy, insert, quality assurance, prostate, seeds, well chamber.

Purpose

In prostate permanent brachytherapy it is necessary to assay the air-kerma strength (S_K) of the ^{125}I seeds provided by the manufacturer. The quality assurance (QA) procedures established by the American Association of Physicist in Medicine (AAPM) and European Society for Radiotherapy and Oncology (ESTRO) [1, 2] state that a random sample containing at least 10% of the seeds has to be assayed. If the seeds are purchased in a sterile configuration, then a number of non-sterile loose seeds equal to 5% of the total number of seeds or five seeds (whichever is fewer) has to be measured. If the mean value of the measured seeds strength for the assay batch disagrees with the data provided by the manufacturer by more than 3%, the users need to investigate the origin of such disagreement, whereas an unsolved disagreement exceeding 5% warrant reporting it to the manufacturer.

Different studies and approaches have been published to improve and facilitate quality control on permanent brachytherapy [3, 4, 5, 6, 7, 8, 9]. Among them, a simple and straightforward solution was proposed by Perez-Calatayud *et al.* [9]. The authors designed an insert to measure the average air-kerma strength of ten seeds in a single measurement using the SourceCheck flat ionization chamber 34051 (PTW-Freiburg, Germany). Recently, the production of that ionization chamber has been discontinued by the manufacturer, and the company has released the new cylindrical chamber SourceCheck $^{4\pi}$ 33005 PTW. Because the geometry of the old and new chambers are different, and the seeds are measured using a different setup (horizontal in the old chamber and vertical in the new one), it is not possible to use the insert designed by Perez-Calatayud *et al.* [9] together with the new cylindrical chamber.

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The purpose of this work is to present a new insert (named “Valencia-PTW insert” in this study), its characterization and the associated methodology that has been designed to be adopted in clinical routine. In this study, it has been applied to the afterloader system seedSelectron® (Nucletron, an Elekta company, Elekta AB, Stockholm, Sweden) [10] and the ¹²⁵I selectSeed™ (Isotron, Isotopentechnik GmbH, Berlin, Germany) but it can be also used with other seed models that are either loosed or in a strand. The procedure is similar to the one described by Perez-Calatayud *et al.* [9] but the insert has been intended to be used together with the SourceCheck⁴ⁿ 33005 ionization chamber from PTW, which has a different geometry and a flat response zone shorter than the SourceCheck flat ionization chamber 34051.

Material and methods

Well-ionization chamber, inserts and seeds

The procedure presented in this study to easily and quickly evaluate the mean air-kerma strength of a set of up to ten seeds requires the following materials:

1. The well-ionization chamber SourceCheck⁴ⁿ 33005 PTW (Figure 1A). It has a sensitive volume of 116 cm³, being 15.00 ± 0.02 cm long, with a diameter of 3.205 ± 0.005 cm. Its reference point is located at 6.3 cm from the well base (SourceCheck⁴ⁿ User Manual D933.131.00/01 PTW Freiburg). This chamber is provided with an insert (named “PTW insert” in this study, see Figure 1B) used to measure the S_K of one single seed by using the calibration coefficient provided by the manufacturer.
2. The “Valencia-PTW insert” developed in this study (Figure 2), which is made of PMMA. It was manufactured by SIHO (SIHO SL, Vigo, Spain) and will be distributed by PTW Dosimetría Iberia (Valencia, Spain). It incorporates a conduit to accommodate ten seeds. Together with the aforementioned well-chamber, this insert is used to perform a single measurement of up to ten seeds (4.5 cm length) to obtain the average air-kerma strength of the set, $\overline{S_K}$. To optimize the seed measuring procedure, the “Valencia-PTW insert” has been designed with a transparent casing to provide structural support with an outer diameter adequate to fit within the well-chamber cavity (Figures 2A and 2B). The applicator is air-filled to provide minimum signal attenuation but for a thin crystal conduit (i.e. a narrow diameter crystal tube) where up to 10 seeds and/or spacers can be allocated. A funnel is located at its top to facilitate the introduction of the seeds (Figure 2B). Underneath the applicator, a narrow hole allows to easily remove the seeds by means of a thin wire provided with the prototype (Figure 2C).
3. A separate non-sterile container with ten ¹²⁵I selectSeed™. An agreement was reached with the seeds manufacturer, so a non-sterile set of ten seeds of the same batch and class as the ones used in the patient implant, suitable to be used in the measurement, was provided to the users. This set of seeds could be measured even several days prior to the implant. Additionally, in order to characterize the “Valencia-PTW insert”, a set

of nine dummy (non-radioactive) seeds is required for the purpose described below.

Methodology proposed in clinical routine

The mean air-kerma strength $\overline{S_K}$ of ten non-sterile seeds of the same batch and class as the ones used for the patient implant can be measured using the following procedure. First, the ten seeds are inserted into the “Valencia-PTW insert” as shown in Figure 2A. Second, this insert is placed inside the well-ionization chamber (Figure 1A). The overall reading $R_{Valencia-PTW}$ is recorded, and $\overline{S_K}$ is then evaluated using:

$$\overline{S_K} = \frac{R_{Valencia-PTW}}{n_s} \times k_{p,T} \times f_{PTW} \times f_{Valencia/PTW}, \quad (1)$$

where $n_s = 10$ is the number of seeds assayed, $k_{p,T}$ is the correction factor for climatic conditions (pressure and temperature), f_{PTW} is the calibration coefficient of the “PTW insert” that is provided by an accredited laboratory for the SourceCheck⁴ⁿ chamber, and $f_{Valencia/PTW}$ is the ratio between the calibration coefficient of the “Valencia-PTW insert” and the calibration coefficient of the “PTW insert”.

$f_{Valencia/PTW}$ takes into account the different response of the chamber when the two different inserts and setups are used. It accounts for the non-flat response of the chamber, the different geometry of both inserts, and the inter-seed perturbation when several seeds (radioactive or not) are measured together in a train. The methodology followed to determine this factor is presented in the next section.

Characterization of the “Valencia-PTW insert”

In the commissioning of the well-chamber and the “Valencia-PTW insert”, it is necessary to determine the

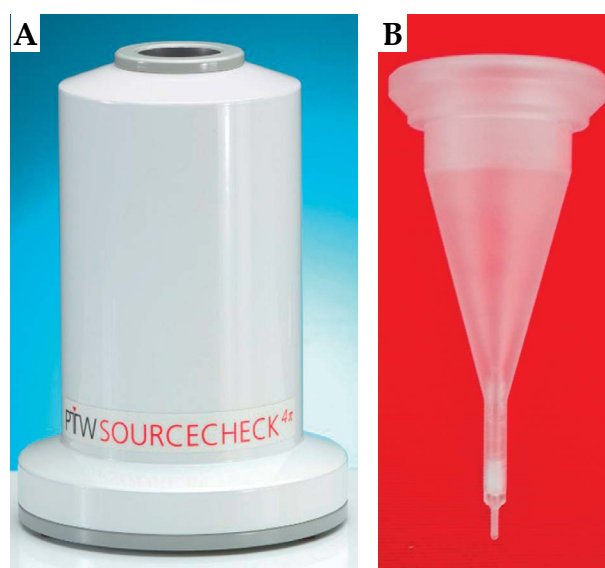


Fig. 1. A) Well-ionization chamber SourceCheck⁴ⁿ 33005 PTW, and B) “PTW insert” used to measure the air-kerma strength of one single seed

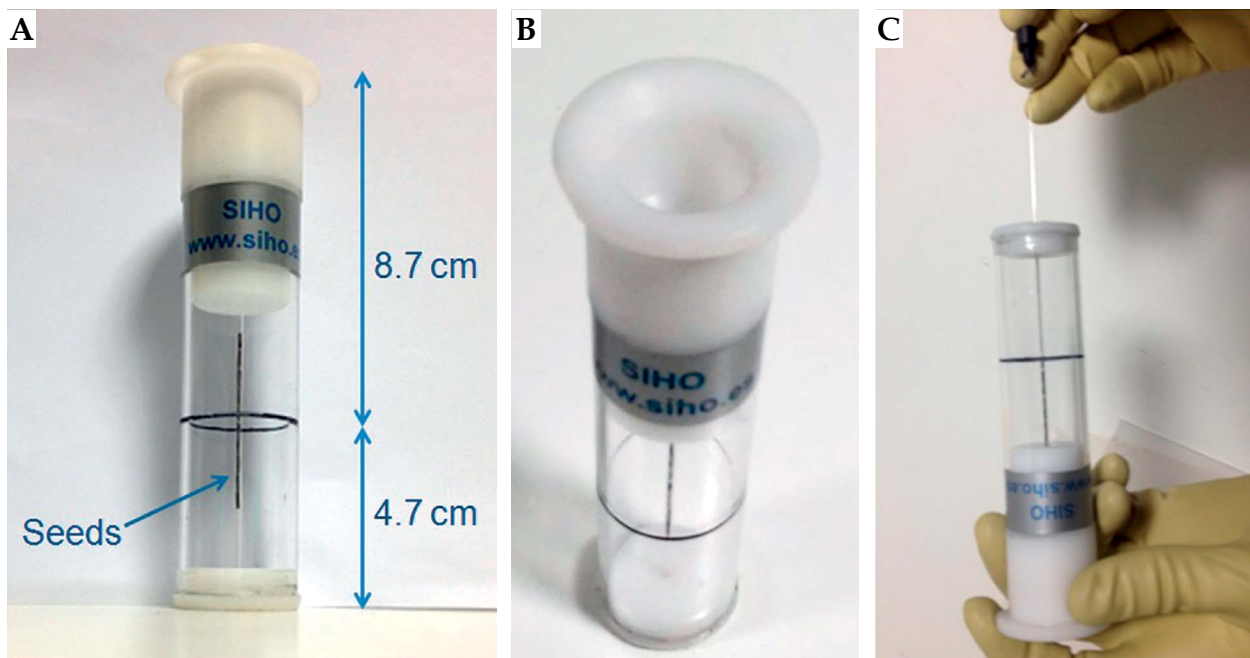


Fig. 2. “Valencia-PTW insert” designed in this study. In **A)** and **B)** it is shown filled with a train of ten seeds, whereas in **C)** it is shown how to ease the extraction of seeds with a wire. The circular mark over the transparent casing shows the position between the fifth and sixth seed

calibration coefficient $f_{Valencia/PTW}$. The following procedure was used. First, one single radioactive seed was assayed with the “PTW insert” (Figure 1B) and the SourceCheck⁴ⁿ chamber. The reading of the chamber R_{PTW} was recorded. This step was repeated three times and results were averaged. Second, this seed was introduced into the “Valencia-PTW insert” together with other nine non-radioactive seeds, which were used to simulate the attenuation and perturbation conditions of a seed when ten seeds are measured at the same time. One reading R_i was taken with the active seed placed at each of the ten possible seed positions in which it can be ordered within the “Valencia-PTW insert”, filling the remaining seed positions with the nine non-radioactive seeds. This second step was also repeated three times and results were averaged. Then, $f_{Valencia/PTW}$ is given by:

$$f_{Valencia/PTW} = \frac{R_{PTW}}{\frac{1}{n_s} \sum_{i=1}^{n_s} R_i} \quad (2)$$

Validation of the proposed method

It was checked whether the proposed method using the new “Valencia-PTW insert” provides compatible results with the mean value of the individual measurement of S_K of each seed using the “PTW insert”. For this purpose, a different set of ten radioactive seeds was used. The S_K of each seed was individually evaluated three times using the “PTW insert” and the following expression was used:

$$S_K = f_{PTW} \times R_{PTW} \times k_{p,T} \quad (3)$$

where the recombination and polarity correction factors have been neglected. Then, the mean S_K value of all ten seeds was calculated. This value was compared with the mean air-kerma strength \bar{S}_K of the ten seeds measured with the “Valencia-PTW insert” and Eq. (1), using the calibration coefficient calculated from Eq. (2). Three independent measurements were also performed with the “Valencia-PTW insert” with the ten seeds, changing the order of the seeds randomly from reading to reading.

Results

Characterization of the “Valencia-PTW insert”

Using the methodology previously described and Eq. (2), the calibration coefficient for the “Valencia-PTW insert” relative to the one of the “PTW insert” results $f_{Valencia/PTW} = 1.135 \pm 0.007$. The overall uncertainty ($k = 1$) considers in quadrature the type A statistical uncertainty of three independent measurements of R_{PTW} and the type A statistical uncertainty of three independent measurements of $\sum_{i=1}^{n_s} R_i$ (see Eq. (2)).

Figure 3 shows the relative response of the chamber against seed position. It is compared to the profile of the SourceCheck flat ionization chamber 34051 and the “Nucletron insert” (from [9]). It is noted that the distance between seed centers was 1 cm for the old insert and 0.45 cm for the new one. This achieves that besides the fact that the new chamber has a shorter flat response, the relative profile when measuring ten seeds is similar in both cases.

Validation of the proposed method

The certificate of calibration provided by the manufacturer (Eckert & Ziegler BEBIG GmbH, Berlin, Germa-

ny) indicates that the set of ten seeds had an air kerma strength per seed of 0.663 U. Taking into account the decay, the air kerma strength per seed was 0.648 U at the date the measurements were performed.

The calibration coefficient provided by the accredited laboratory of PTW for the system formed by the SourceCheck⁴ⁿ 33005 PTW, the "PTW insert" and the ^{125}I select-Seed is $f_{PTW} = N_{S_K} = 6.207 \times 10^5 \text{ Gy} \times \text{m}^2 / (\text{h} \times \text{A})$ ($\pm 1.4\%$, $k = 1$). Using this calibration coefficient, the "PTW insert" and Eq. (3), the mean air-kerma strength calculated from the individual S_K of each of the ten radioactive seeds was $\sum_{i=1}^{10} S_{K_i} / 10 = 0.646 \pm 0.010 \text{ U}$. For the batch of ten seeds considered, the minimum and maximum differences between the S_K measured of each seed and the mean value were -3.3% and $+3.6\%$, respectively. The mean air kerma strength deviates only by -0.3% from the value certified by the manufacturer.

The mean air kerma strength obtained from the three independent measurements with the "Valencia-PTW insert" and Eq. (2) was $\overline{S_K} = 0.636 \pm 0.010 \text{ U}$. This value deviates by -1.8% from the value certified by the manufacturer. The overall stated uncertainty includes also the component due to the standard deviation between three independent measurements (0.13%).

Therefore, the values calculated from both methods are in agreement between them and also with the value certified by the manufacturer, considering the stated uncertainties ($k = 1$).

Discussion

This paper provides the methodology recommended to characterize the new insert and to use it routinely in clinical practice. Each user of a new SourceCheck⁴ⁿ 33005 PTW and a new "Valencia-PTW" insert has to evaluate its own calibration coefficient in case differences in the manufacturing of the insert or in the chamber response exist.

This study suggests assaying the mean air-kerma strength of ten seeds in a single measurement in order to fulfill the AAPM-ESTRO recommendations. However, if desired by the user, the mean value of a smaller set of seeds can be evaluated with the same insert, although a different calibration coefficient is required for each number of seeds (n_s) assayed. If using the insert for fewer than ten seeds, the source train should be ideally centered to take profit of the higher uniformity of the response of the chamber.

An alternative solution to the one proposed in this study is to use the "PTW insert" provided by the chamber manufacturer, which allows measuring the air-kerma strength of one single seed at a time. However, that methodology is more time consuming and requires a higher manipulation of the seeds. The measuring time is reduced roughly by a factor of ten with the new insert. It is also noted that with the "PTW insert" the ten seeds have to be manipulated individually, whereas with the "Valencia-PTW insert" all ten seeds can be moved directly from their container to the insert by using its funnel (see Figure 2B). Hence, there is no direct manipulation of the seeds with the new insert. Therefore, the insert and methodology here designed are more efficient and safer from radiation protection point of view.

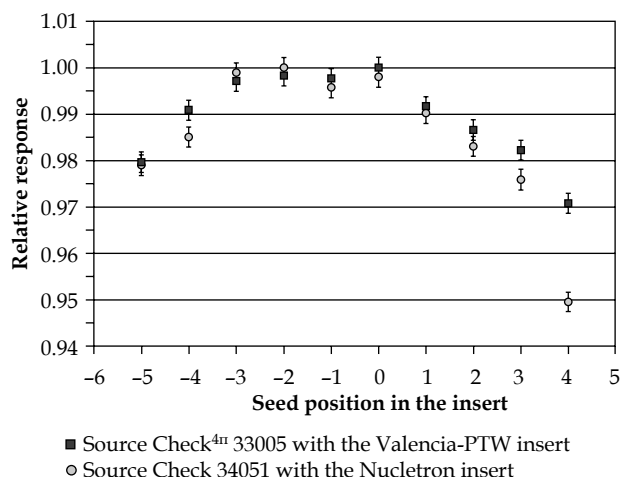


Fig. 3. Relative response of the new chamber and the "Valencia-PTW insert" against seed position. It is compared to the profile of the flat ionization chamber 34051 and the "Nucletron insert" (from [9])

Conclusions

A practical solution that can be adopted in clinical routine by the users to fulfill the AAPM-ESTRO recommendations regarding QA of seeds used in prostate permanent brachytherapy has been presented. It is based on the new "Valencia-PTW insert" that has been designed to be used together with the new well-ionization chamber SourceCheck⁴ⁿ 33005 PTW. The system allows evaluating the mean air-kerma strength of up to ten ^{125}I seeds with one single measurement. A method to characterize the system and to use it in clinical routine has been presented and validated. The method proposed is faster and more efficient from radiation protection point of view than assaying each single seed at a time, and provides consistent results. It is especially adequate for easy implementation in the workflow of clinical practice.

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Disclosure

Authors report no conflict of interest.

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