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Original research article

Calibration of ^{192}Ir high dose rate brachytherapy source using different calibration procedures

*Shwetha Bondel**, *Manickham Ravikumar*, *Sanjay Sudhakar Supe*, *Buchuppudi Rekha Reddy*

Department of Radiation Physics, Kidwai Memorial Institute of Oncology, Hosur Road, Bangalore 560 029, India

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ABSTRACT

Aim: To calibrate Ir-192 high dose rate (HDR) brachytherapy source using different calibration methods and to determine the accuracy and suitability of each method for routine calibrations.
Background: The source calibration is an essential part of the quality assurance programme for dosimetry of brachytherapy sources. The clinical use of brachytherapy source requires an independent measurement of the air kerma strength according to the recommendations of medical physics societies.
Materials and methods: The Ir-192 HDR brachytherapy source from Gammamed plus machine (Varian Medical Systems, Palo Alto, CA) was calibrated using three different procedures, one using the well-type ionization chamber, second by the in-air calibration method and third using solid water phantoms. The reference air kerma rate (RAKR) of the source was determined using Deutsche Gesellschaft fur Medizinische Physik (DGMP) recommendations.
Results: The RAKR determined using different calibration methods are in good agreement with the manufacturer stated value. The mean percentage variations of 0.21, −0.94, −0.62 and 0.58 in RAKR values with respect to the manufacturer quoted values were observed with the well-type chamber, in-air calibration, cylindrical phantom and slab phantom measurements, respectively.
Conclusion: Measurements with a well-type chamber are relatively simple to perform. For in-air measurements, the indigenously designed calibration jig provides an accurate positioning of the source and chamber with minimum scatter contribution. The slab phantom system has an advantage that no additional phantom and chamber are required other than those used for external beam therapy dosimetry. All the methods of calibration discussed in this study are effective to be used for routine calibration purposes.

* *Corresponding author at*: Department of Radiation Physics, Kidwai Memorial Institute of Oncology, Hosur Road, Bangalore 560 029, Karnataka, India. Tel.: +91 80 26094043; fax: +91 80 26560723.
E-mail address: shwetha0828@yahoo.co.in (S. Bondel).
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1. Background

Brachytherapy is considered as an essential part of the treatment for almost all the sites of cancers.[1] High Dose Rate (HDR) brachytherapy has been widely accepted over the past two decades, particularly for the treatment of gynaecological tumours and for tumours at other sites which are not easily accessible for Low Dose Rate (LDR) techniques. With the improved localization techniques and advanced treatment planning systems, it is now possible to have precise and reproducible dose delivery. However, desired clinical results can only be achieved with a good clinical and dosimetric practice.

The clinical use of brachytherapy source requires an independent measurement of the air kerma strength according to the recommendations of the medical physics societies. The recommended quantity by International Atomic Energy Agency (IAEA)[2] for the specification of gamma sources is the reference air kerma rate (RAKR), defined by the ICRU[3–5] as the kerma rate to air, in air, at a reference distance of 1 m, corrected for air attenuation and scattering. The Netherlands Commission on Radiation Dosimetry (NCS)[6] states that the uncertainty in dose specification for brachytherapy due to physical procedures should be less than ±5%. The calibration certificate issued by the manufacturer quotes source strength with an overall uncertainty of ±5%. Hence, calibration of brachytherapy source at the user level is necessary not only to check manufacturer stated calibration but to ensure traceability to internationally accepted standards.[1,2]

The American Association of Physicists in Medicine (AAPM) states that any institution planning to provide brachytherapy should have the ability to independently verify the source strength provided by the manufacturer.[7] A benchmark data set of brachytherapy HDR and pulsed dose rate (PDR) quality control (QC) testing has been presented by a comprehensive survey undertaken in the United Kingdom (UK) radiotherapy centres which is representative of practice across the UK.[8] Calibration of ^{192}Ir source is generally performed using a well-type ionization chamber or a cylindrical ionization chamber. But the Task Group for Afterloading Dosimetry of the Deutsche Gesellschaft fur Medizinische Physik (DGMP) recommends specially calibrated solid-state phantoms which can provide higher reproducibility and better accuracy in calibration of brachytherapy sources.[9] A study conducted to compare the results of the three years of HDR and PDR source activity control procedure showed that dosimetry systems using well-chamber and thimble chamber are fast and reliable tools for checking ^{192}Ir source parameters in working brachytherapy departments.[10]

2. Aim

The aim of the present study was to calibrate ^{192}Ir high dose rate (HDR) brachytherapy source using different calibration methods and to determine the accuracy and suitability of each method for routine calibrations. The second purpose was to determine the accuracies of the different methods with reference to the well-type chamber measurements.

3. Materials and methods

The Gammamed Plus ^{192}Ir source from Gammamed plus machine (Varian Medical Systems, inc., Palo Alto, CA) is 4.52 mm long with an active length of 3.5 mm. The source capsule has an outer diameter of 0.9 mm, active diameter of 0.6 mm and a stainless steel encapsulation. The source was calibrated using three different procedures, one using the recommended well-type chamber, second by the in-air calibration method and third by using solid phantoms. Two types of solid phantoms were used; a cylindrical PMMA phantom and a solid phantom of white polystyrene slabs. Each method of calibration was repeated periodically ($n = 6$) to verify the consistency in the readings.

The technical specifications of the ionization chambers used in this study are given in Table 1. The calibration procedures using each of the above mentioned methods are discussed below.

3.1. *Well-type ionization chamber*

The use of a well-type ionization chamber for HDR source calibration is the recommended procedure by AAPM[11] to simplify the calibration process and it has been evaluated by several authors.[12–16] The well-type re-entrant chamber used for the present study is hermetically sealed and contains pure Argon as the fill gas at a pressure of 23.5 psi. The chamber has a diameter of 17.0 cm and 31.3 cm height with an active volume of 1.2 L.

The measurement setup is shown in Fig. 1. The RAKR using a well-type chamber[1,2,16] can be determined from the following expression,

$$(K_a)_a = N_k K_p I_{max} K_{ion}$$

where N_k is the air kerma strength calibration factor given in Gy m^2 h^{-1} A^{-1} at 1 m and taken from the calibration certificate provided by the calibration laboratory. The calibration factor for the well-type chamber used was 7.562×10^4 Gy m^2 h^{-1} A^{-1} at 1 m.

K_p is the correction factor for the change in the temperature and air pressure from the reference chamber calibration

Fig. 1 – RAKR measurement set-up with well-type re-entrant chamber.