Calibration of iridium-192 source by ionization chamber for high dose rate brachytherapy

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▶ ***Technical note***

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ABSTRACT

Background: The effectiveness and safety of brachytherapy treatment is mainly concerned with the calibration of sources and their traceability to internationally accepted Standards. Secondary Standard Dosimetry Laboratory (SSDL) does not offer calibration of ionization chambers with gamma-ray spectrum of high dose rate source ^{192}Ir . This work has been carried out to calibrate the high dose rate (HDR) ^{192}Ir sources. ***Materials and Methods:*** An interpolation procedure, using calibrations above 1.25 MeV (^{60}Co), and below 135 kV X-rays (61.1 keV), the exposure-weighted average energy 397 keV of ^{192}Ir is employed. Using Farmer ionization chamber HDR ^{192}Ir source has been calibrated by free in-air measurement technique and then the calibrated source has been used to calibrate well-type ionization chamber. ***Results:*** Difference between in-air measurement and that of manufacturer's remained within ± 3%, and the difference between in-air measurement and well-type chamber remained within ± 1%. Comparison between well-type measurements and manufacturer values shows differences less than ± 2%. All these differences are within the acceptable tolerance limits. ***Conclusion:*** The method presented shows good degree of accuracy so that the traceability of calibration is assured. Installation of a new brachytherapy source needs to be calibrated by in-air measurement technique and then this calibrated source should be used for well chamber calibration. Brachytherapy community is suggested to calibrate their sources with this method.

Keywords: *Brachytherapy, calibration, ionization chamber, HDR.*

INTRODUCTION

High dose rate remote afterloading brachytherapy equipment, like Gamma Med plus manufactured by Varian Medical systems, are becoming more popular in Pakistan. At present there are six Gamma Med plus and one Varisource HDR system in Pakistan. The radionuclide used in these systems is ^{192}Ir. The initial activity of these sources is round about 10 Ci. The half-life of ^{192}Ir is 83.831 days. The short half-life of ^{192}Ir HDR source requires changing the source at every interval of four months [1-3]. For brachytherapy sources vendors assign large uncertainties to their stated calibration values up to ± 10%. Independent verification as well as exact measurement of source strength is quite significant in order to assure the quality of brachytherapy treatment. To quote the report of

American Association of Physicists in Medicine (AAPM) Task Group-40 [4], "Each institution planning to provide brachytherapy should have the ability to independently verify the source strength provided by the manufacturer" as well as to use institutional physicist's measured value in performing dosimetry calculations [5]. Also in BSS 115 "Registrant and licensees shall ensure that the calibration of sources used for medical exposure be traceable to a Standards Dosimetry Laboratory" [6].

Secondary Standards Dosimetry Laboratory (SSDL) a department of Pakistan Institute of Science and technology (PINSTECH) under the control of Pakistan Atomic Energy Commission (PAEC), Islamabad, provides calibration facility to all cancer hospitals including BINO for the dosimetry systems, which are being used for the calibration of external beams. Since the calibration of well-type chamber dosimetry system had become due and required to be carried out under Pakistan Nuclear Regulatory Authority (PNRA) regulations, we therefore, contacted SSDL for the calibration of dosimetry system, used for the calibration of (HDR) brachytherapy sources (^{192}Ir). However, SSDL had no facility for the calibration of HDR Ir-192 and dosimetry system. As per SSDL advice, we contacted KIRAN Karachi and NORI Islamabad, the other two users of ^{192}Ir HDR in Pakistan, for carrying out the required calibration but we learnt that they were also facing the same problem. We then looked for other avenues.

Initially, University of Wisconsin (UoW), USA had calibrated our system. There are possibly two solutions for us. One was to send the system to UoW USA, the other was to calibrate our source by in-air measurement technique, which is the recommended technique of American Association of Physicists in Medicine (AAPM) [7], International Atomic Energy Agency (IAEA) [8] and European Society for the Radiology and Oncology (ESTRO) [9] and traceable to International Standards. The second solution would not only solve our problem back home but also set precedence for calibration in this field in Pakistan. The aim of this study was to calibrate the ^{192}Ir source. The recommended quantity for specifying the strength of brachytherapy sources is air kerma strength [10-11]. Recommendations of IAEA, AAPM, ESTRO and PNRA demand that the method of calibration should be traceable to International Standards. It was aimed to use In-air measurement technique of calibration to determine a convenient and efficient method of source calibration.

MATERIALS AND METHODS

The Ir^{192} source was initially calibrated by in-air measurement technique, using Farmer type ionization chamber and then the calibrated source has been used to calibrate the well-type chamber. This work intended to calibrate the source using the calibrated well chamber for being an easier, efficient and reproducible method.

Determination of air kerma calibration factor (N_K) for the ionization chamber

The 0.6-cm^3 Farmer ionization chamber (PTW Freiburg, Germany, Sr. No. N30006-0072) and UNIDOS Universal Dosimeter has been used for this study. There is no Primary Standards Dosimetry laboratory (PSDL) in Pakistan (no primary standard exists for HDR ^{192}Ir [8, 12]; only one SSDL is present in Pakistan under the network of SSDLs by the IAEA. Calibration factor (48.110 mGy/nC & 46.962 mGy/nC) for ^{60}Co beam with build-up cap and 135 kV X-ray beam without build-up cap (external beams) respectively was obtained from SSDL for the said dosimetry system. The air kerma weighted average energy of an ^{192}Ir source is 397 keV, which lies between the energy of ^{60}Co (1.25 MeV) and effective energy (61.1 keV) of 135 kV X-ray beam, with added filtration of 1.0 mm Al and 0.30 mm Cu and an HVL of 0.5 mm Cu. Since SSDL has no facility for the calibration of HDR Brachytherapy sources (^{192}Ir), therefore, the air-kerma calibration factor is obtained by an interpolation of these two energies as approved in IAEA-TECDOC-1274 2002 [8]. This becomes the de facto primary standard [13].

Now by using the following equation, we obtain the $N_{k, Ir}$ (calibration factor for Ir);

$$Nk,Ir = \frac{[f_{w,135KV} \cdot A_{w,135kV} \cdot N_{k,135kV} + f_{w,Co} \cdot A_{w,Co} \cdot N_{k,Co}]}{A_{w,Ir}} \quad (1)$$

$$=47.777\, mGy/nC$$

where the values of A_w (wall correction factor) for ionization chamber used for the present study is 0.997 for 135kV X-rays, 0.985 for ^{192}Ir gamma rays and 0.991 for ^{60}Co gamma rays for a PMMA build-up cap of 0.550 gm/cm^2 [(14)].

In-air measurement technique

The air kerma were measured at multiple source–chamber distances i.e. at 10, 15, 20, 25, 30, 35, 40-cm and these values were corrected for inverse square law to get the reference air kerma value (air kerma at one meter distance). Dosimeter timer was used for charge measurement to avoid any error due to the transit dose. The temperature and pressure were recorded during the measurement.

The mean of the five readings measured at each distance was corrected for temperature and pressure, air attenuation, non- uniformity, scattered radiation contribution and inverse square law.

Determination of calibration factor for Well-type chamber

Once the HDR ^{192}Ir source is calibrated. It was used for the calibration of well type chamber.

Calibration of an ^{192}Ir source using well-type chamber

Once the calibration factor of the well chamber is determined. It can be used for the calibration of sources because it is an easier and reporducable method.

The air kerma rate has been determined using the equation given below;

$$K_R = M_{u.} k_{PT.} N_{elec\,.} N_K \quad (2)$$

where K_R is the reference air kerma rate of the source and M_u is the scale unit reading, k_{PT} and k_{recom} are correction for temperature & pressure and recombination losses, respectively.

RESULTS AND DSCUSSION

Determination of reference air kerma rate was the first (key) step, which was obtained by in-air measurement technique. The strength of an HDR ^{192}Ir source was determined in terms of air kerma rate at one-meter distance.

Two sources were calibrated at 16 different occasions by in-air measurement technique. The reference air kerma rate has been determined using the following equation;

$$K_R = N_K \,.\, (M_u/t)\, k_{air.}\, k_{scatt.} \,.\, k_n \,.\, k_{PT} \,.\, (d/d_{ref})^2 \quad (3)$$

where N_K is the air kerma calibration factor of the ionization chamber at the actual photon energy; M_u is the measured charge collected during the time t and corrected for ambient temperature and pressure, recombination losses and transit effects during source transfer in the case of afterloading systems; k_{air} is the correction for attenuation of the primary photons by the air between the source and the chamber; k_{scatt} is the correction for scattered radiation from the walls, floor, measurement set-up, air, etc.; k_n is the non-uniformity correction factor, accounting for the non-uniform electron fluence within the air cavity; d is the measurement distance i.e. the distance between the centre of the source and the centre of the ionization chamber; d_{ref} is the reference distance of 1 m.

For air attenuation and non- uniformity correction TECHDOC-1274 [(8)] was used and interpolate the values for the required source to chamber distances. Scattered radiation correction was determined by multiple distance method [(8)].

The well chamber was placed at distance of more than one meter from the floor as well as from the walls to have minimum scatter contribution. The well chamber behavior and other various factors that influence the result have been determined experimentally. The maximum response point of the chamber was obtained for source position at height of 51 mm from the bottom of the chamber. The ion collection efficiency of the well type chamber was about 99.95 % with 300 V applied. The results related to chamber parameters were in good agreement with the data provided by the manufacturer.

The role of air kerma rate in the clinical dose calculation is well accepted. All radiation oncology physics concern associations recommend getting the value of air kerma rate from an independent setup. The aim of our attempt is two folds; one to follow the recommended protocols and second is to have the measured values of dose calculation parameters, in order to improve accuracy in brachytherapy treatment.

The measurements of reference air kerma rate of HDR ^{192}Ir source have been continuously taken with the intervals of almost one week. The values of reference air kerma rate are also This difference is not beyond the acceptable tolerance limit given by the manufacturer i.e. ± 5%.

Well chamber has been calibrated resultantly. After this, the calibrated well chamber has been used to measure reference air kerma rate of the HDR ^{192}Ir. The obtained results are compared with the previously measured air kerma rate values. This comparison is presented in table 2.

Dosimetry systems. In table 1 the measured air kerma rate with in-air measurement technique is compared with the manufacturer provided values and in the table 3 the measured air kerma rate by well chamber dosimetry system is compared with the vendor's provided values. The latter shows less percentage difference than former, indicating relatively higher degree of accuracy of air kerma rate measured by well chamber. Since, this well chamber dosimetry system is calibrated by in-air measurement determined reference air kerma rate, it is showing close matching values with that of vendor's provided values, but the role of in-air measurement is still elementary as it provides the base to calibrate the well chamber. All the results obtained are useful in order to be used for dose calculation, as well as this accurate determination of dose calculation parameter always gives great confidence to the Physicists. The results are presented in table 1-3, were taken at different times, with an interval of one week. Constancy checks of well-type chamber has been carried out after the interval of one month under Co-60 beam in reproducible position and results closely match with the accepted values ±1 % [12].

Table 1. Comparison between Values of Reference Air Kerma Rate (K_R(m) as measured by using in-air measurement technique and values on source certificate provided by vendor K_R (c) , at different times (with a time interval of one week).

Sr. no	K_R(m)	K_R (c)	% Difference
1	17.4	16.9	2.8
2	16.2	15.8	2.4
3	15.2	14.8	2.8
4	13.4	13.0	2.7
5	34.9	34.4	1.4
6	33.5	32.8	2.0
7	31.2	30.7	1.7
8	29.0	28.5	1.7
9	25.2	25.0	0.9
10	24.0	23.6	1.8
11	22.6	22.1	2.3
12	21.1	20.7	2.1
13	17.4	17.0	2.3
14	15.0	14.8	1.6
15	12.9	12.8	1.1
16	12.1	12.0	0.9

Note: *Sr. 1-4 for source 1 and Sr. 5-16 for source 2.*

Table 2. Comparison between values of Reference Air Kerma Rate (K_R(m)) as measured by in-air measurement technique and well-type measurement technique (K_R (mw)), at different times (with a time interval of one week).

Sr. no	K_R(m)	K_R (mw)	% Difference
1	33.5	33.4	0.34
2	31.2	31.2	-0.03
3	29.0	29.0	0.07
4	25.2	25.4	0.74
5	24.0	24.0	0.14
6	22.6	22.5	0.66
7	21.1	21.0	0.41
8	17.4	17.3	0.64
9	15.0	15.0	0.21
10	12.9	13.1	0.90
11	12.1	12.2	0.92

Table 3. Comparison between values of Air Kerma Rate (K_R (mw)) as measured by well-type measurement technique and values on certificate as provided by vendor (K_R (c)) , at different times (with a time interval of one week).

Sr. no	K_R(mw)	K_R (c)	% Difference
1	33.4	32.8	1.6
2	31.2	30.7	1.7
3	29.0	28.5	1.6
4	25.4	25.0	1.6
5	24.0	23.6	1.7
6	22.5	22.1	1.7
7	21.0	20.7	1.7
8	17.3	17.0	1.6
9	15.0	14.8	1.4
10	13.1	12.8	2.0
11	12.2	12.0	1.9

CONCLUSION

Accurate determination of treatment dose for brachytherapy treatment always requires accurate dose calculation parameters. Reference air kerma rate is a key parameter, which is used as input in the treatment planning system for the dose calculation. A newly installed brachytherapy source can be calibrated by in-air measurement technique and then this calibrated source should be used for well chamber calibration. The source strength should be determined accurately for clinical use, as manufacturer's calibration is not assumed to be precise enough on its own. The routine dosimetry should be done with this calibrated well chamber because well chamber dosimetry system is easy to use, reproducible, convenient and comparatively less time consuming.

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