STANDARDIZATION OF IRIDIUM-192 COILED SOURCE IN TERMS OF AIR KERMA OUTPUT

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Abstract

ICRU (1985) recommended that the output of gamma ray brachytherapy sources should be specified in terms of reference air kerma rate, defined as the kerma rate to air in air at a reference distance of 1 meter, perpendicular to the long axis of the source, corrected for air attenuation and scattering. As these measurements are difficult to carry out in the routine clinical use, it is the common practice to calibrate the re-entrant ionization chamber with respect to open air measurements and use the re-entrant chamber for routine measurements. This paper reports on the measurements carried out to correlate the nominal activity and air kerma rate of ^{192}Ir wire sources supplied by the Board of Radiation and Isotope Technology, Department of Atomic Energy.

Introduction :

One of the major factors which contributes towards dosimetric accuracy in brachytherapy is assessment of source strength used. According to ICRU Report 38 (1985), the specification of gamma ray brachytherapy sources should be in terms of reference air kerma rate , defined as kerma rate to air, in air at a reference distance of one meter from the center of source and perpendicular to the long axis of the source. The long distance measurement geometry minimizes the dependence of the calibration upon the construction of the source and detector, as both can be considered as points and effect of oblique transmission of gamma rays through source sheathing become negligible. But the long distance measurements under scatter free conditions are difficult to carry out in routine practice, especially with low activity sources. Hence it is a common practice to establish a calibration factor for the well chamber with respect to open air measurements and use the well chamber along with a reference standard for routine calibrations [1,2]. Under the EUROMET framework, a program of work was initiated at NPL to confirm the traceability to NPL secondary standard radionuclide calibrator of air kerma rate measurements made by Amersham International for wire sources of ^{192}Ir [3].

In India, radiation sources are supplied by the Board of Radiation and Isotope Technology (BRIT), Department of Atomic Energy. ^{192}Ir wire sources used for interstitial therapy is supplied to hospitals in the form of cylindrical coils, the nominal activity of which is measured in a re-entrant 4π gamma chamber. The coil is cut into required lengths by the users. This paper deals with the measurements carried out to correlate the nominal activity of coiled source with reference air kerma rate measured for coiled as well as linear form of sources.

Materials and Methods

^{192}Ir wire sources supplied by BRIT consists of iridium-platinum core (75 % platinum & 25 % iridium) of 0.1 mm diameter with 0.1 mm thick platinum coating, thus making an overall diameter of 0.3 mm. The wire in lengths of 50 or 100 cm is coiled and activated by thermal neutron irradiation in a reactor. The nominal activity of the coil is then measured in a calibrated well type ionization chamber and supplied to the users.

Measurements

An ^{192}Ir source of 3.7 GBq(100 mCi) produces an exposure rate of about 3.225 * 10^{-9} A/Kg (12.5 μR/sec) at one meter. The current per unit volume works out to be about 4.17 * 10^{-15} A/cm^3. To measure such low currents, a 400 c.c. ionization chamber coupled to a varactor diode amplifier with a calibrated capacitor in the feed back was used. The 400 c.c. bakelite chamber was calibrated against a spherical graphite chamber whose accuracy of air kerma rate determination is 2 % and the measurements are traceable to the ^{60}Co therapy level primary standard which is intercompared against international standards.

Iridium wire cut into small pieces of 1.5 cm length, irradiated to an activity of 222 MBq/cm (6 mCi/cm) was procured from BRIT for the calibration of 400 cc chamber. The sources were arranged in a matrix of size 1.5 cm x 2.0 cm and aligned in level with the center of spherical graphite chamber, 65 cm apart in a scatter free geometry. The source - detector alignment was verified using a laser beam. The chamber was connected to varactor amplifier set up with a calibrated capacitor in the feedback. The output voltage (V), over a time t seconds, was measured and corrected for background radiation, charge leakage, temperature and pressure. Corrections have also been applied for wall attenuation (K_{att} = 1.066) , stopping power ratio of graphite to air (S/ρ = 1.015). KCEP and (μ_{en}/ρ) were assumed to be 1.0 for energy corresponding to ^{192}Ir gamma rays. Current per unit volume was evaluated and correlated to air kerma rate. The graphite chamber was then replaced with 400 cc bakelite chamber and measurement was repeated as before. After applying necessary corrections for background radiation, charge leakage, temperature and pressure, current per unit volume was evaluated. The ratio of the two sets of readings was taken as the calibration factor of the 400 cc chamber.

The calibrated 400 cc chamber was then used to standardize the ^{192}Ir coils actually used in clinical practice. Two sets of measurements were carried out, one with the source in the coil form, as supplied to the users and the other after cutting into linear form, as used in clinical practice. ^{192}Ir coiled source and the chamber were aligned in a scatter free geometry. The source chamber distances were kept as 75 cm and/or 100 cm. Measurements were carried out as before and after applying the necessary corrections discussed earlier, current was calculated and using the calibration factor of the chamber, air kerma rate was evaluated. Measurements were carried out for five different coils, 1 of 100 cm and 4 of 50 cm each. Correction for decay of source activity during the course of measurement was applied assuming a half life of 73.83 days. Reference air kerma rate per unit length was evaluated as $\mu Gy.h^{-1}.m^2/cm$.

Three of these coils, one of 100 cm and the other two of 50 cm each were then cut into linear sources, varying in length from 6 cm to 10 cm. Channels were drilled at 1 cm intervals in a perspex sheet and the nylon tubing used for implantation was fixed into these.

The perspex sheet and the 400 cm^3 ionization chamber were aligned in a geometry identical to coil source measurement. ^{192}Ir wires loaded in inner nylon tubings were then inserted into the outer nylon tubings fixed on the perspex sheet. Air kerma rate was measured as before. To account for the possible loss of small bits of wire while cutting, the actual length of wire used for measurement was determined from auto- and X-ray radiographs. Autoradiograph also helped to ensure the uniformity of activity. Reference air kerma rate per unit length was evaluated and correlated to that measured for coiled source.

Discussion

Dose computation for linear sources require specification of source strength in terms of reference air kerma rate(RAKR) constant ($\mu Gy.h^{-1}.m^2.MBq^{-1}$). This was calculated from the measured reference air kerma rate using the quoted nominal activity of the source and assuming the coil as a series of rings of diameter 1.2 cm spaced at equal intervals for coil form and using Sievert`s line source dose function, for linear form. The values thus obtained for sources in coil and linear forms are given in Table - 1. The correction factor to be used for linear source output is given as ratio of RAKR constants in the last column of the Table.

Table - 1

Measured Output Correction Factor for ^{192}Ir Coils

Source Chamber Distance (cm)	RAKR Constant ($\mu Gy.h^{-1}.m^2.MBq^{-1}$) Coil	Linear	Ratio of RAKR Constant Linear/Coil
75.0	0.1025 ± 0.0013	0.1124 ± 0.0019	1.101
100.0	0.1035 ± 0.0009	0.1156 ± 0.0021	1.118

It may be seen that the RAKR constant for linear form is significantly higher than that of coiled form. This could be attributed to higher inherent self shielding for coil. In clinical practice , where long wires are used, the reference air kerma rate constant measured for linear form should be used for dose computations. As the published values of RAKR constant for ^{192}Ir sources show large variations, the measurements carried out at respective centers should be considered as appropriate.

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