In-air calibration of new high dose rate ^{60}Co brachytherapy sources: results of measurements on a GZP6 brachytherapy afterloading unit

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SUMMARY

BACKGROUND: The air kerma rate of brachytherapy sources should be determined accurately by the manufacturer and medical physicists before clinical use.

AIM: In the current study the air kerma rate of three new ^{60}Co high dose rate (HDR) brachytherapy sources was obtained by in-air measurements and a Farmer type ionization chamber.

MATERIALS/METHODS: Three ^{60}Co sources of a brachytherapy afterloading unit, GZP6, were calibrated in free air using a Farmer type chamber which was calibrated in terms of air kerma in an external teletherapy ^{60}Co beam. Several correction factors including scatter correction and non-uniformity correction factors were derived and used for in-air calibrations.

RESULTS: The measured air kerma rates for all sources were in good agreement (less than 2.5%) with manufacturer-provided data, and the reliability of the air kerma rates of sources was validated for clinical application.

CONCLUSION: In-air calibration of ^{60}Co HDR sources can be performed using a Farmer type ionization chamber with acceptable accuracy. However, accurate distance measurement and reproducible measurement setup are required.

BACKGROUND

The advanced production of artificial isotopes in recent decades and the introduction of remote afterloading techniques allowed the use of radionuclides of high-dose-rate radioactivity (HDR) in brachytherapy. ^{192}Ir and ^{60}Co sources are used frequently for HDR brachytherapy treatments due to their high specific activity [1, 2]. Calibration of brachytherapy sources are performed at the manufacturer's site using a well type chamber or by in-air measurement using a thimble chamber. On the other hand, vendors usually assign large uncertainties to their stated calibration values, in some cases up to ±10%. End-user calibration of brachytherapy sources is necessary, not only to check vendor stated calibration but to ensure traceability to internationally accepted standards [3]. It is also recommended by the American Association of Physicists in Medicine (AAPM) that "Each institution planning to provide brachytherapy should have the ability to independently verify the source strength provided by the manufacturer" [4].

The reference air kerma rate is the recommended quantity for specifying brachytherapy sources [3, 4]. It is defined by the International Commission on Radiation Units and Measurements (ICRU) as the kerma rate to air, in free space, at a reference distance of one metre, corrected for air attenuation and scattering [4]. For needles, tubes and other similar rigid sources, the direction from the source centre to the reference point should be at right angles to the long axis of the source.

In-air calibration using a Farmer type chamber is influenced by several factors which may increase the uncertainty of measurements. Several works have reported the role of these factors and approaches to minimize their effects on measurement accuracy [2, 5–8]. The effect of scattered radiation on in-air

calibration was studied and they concluded that amount of scattered radiation changes with respect to the surrounding concrete scattering surfaces but it becomes constant at a distance greater than 100 cm from the wall of the room. [7, 9].

AIM

In this study the reference air kerma rates of three ^{60}Co HDR sources were measured in air using a Farmer type chamber before clinical use. The results of measurement were compared with the manufacturer-provided air kerma rates of these sources.

MATERIALS AND METHODS

HDR ^{60}Co sources

In-air strength calibration was performed for three HDR ^{60}Co sources of a GZP6 afterloading unit (Nuclear Power Institute of China). This unit uses six linear braid type sources including one stepping and five non-stepping sources for intracavitary treatment such as cervix, rectum, oesophagus and nasopharynx malignancies. The sources consist of ^{60}Co active cylinders (length=3.5 cm, diameter=1.5 mm) sealed by titanium capsules and inactive steel balls (diameter=1.5 mm) which are covered by a steel spring. The position of active elements is constant in the source braid and is not changed for different treatments. Each braid source is situated in a given channel and is loaded independently by a mechanical transport system from a shielded container to applicators for treatment. However, channels 3 and 4 are loaded simultaneously and used for ovoid applicators. A schematic representation of the three sources used in this study is shown in Fig.1.

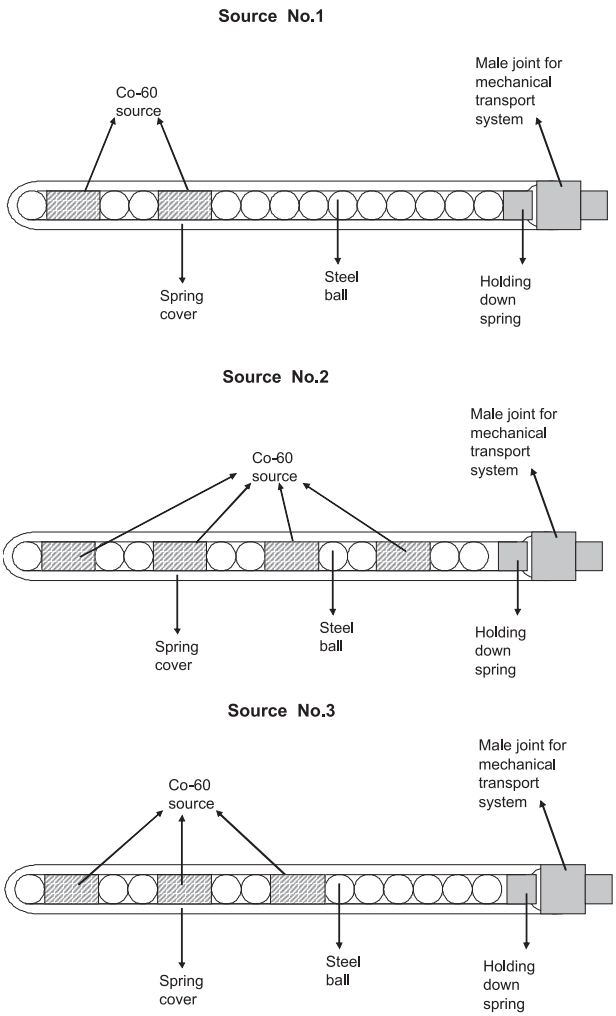

Fig. 1. Schematic diagrams of GZP6 ^{60}Co braid type sources used for intracavitary treatments.

Measurement setup

A Farmer type ionization chamber (FC65-P) with volume of 0.65 cm^3 (Scanditronix/Wellhofer) and a build-up cap (PMMA) with thickness of 0.5 g/cm^2 was used for in-air measurements. The chamber was calibrated in terms of air kerma at the actual photon energy of the brachytherapy source, and the calibration was done in an external photon beam of a ^{60}Co teletherapy unit at the Iranian Atomic Energy Organization.

The applicator was placed on the treatment couch and fixed using its fixation systems. The chamber was placed on the same couch and was fixed using an acrylic holder at various distances from the applicators. The measurement setup is shown in Fig. 2. For each measurement position the vertical position and also the distance from the source applicator was measured using a scale attached to the couch and also by a ruler. This was done independently by two dosimetrists. We assumed a geometric uncertainty of ±2 mm for our measurements. To have reliable measurements the distance between the chamber centre and the centre of the source must be at least 10 times the length of the source in order to ensure that the error introduced due to the point