Radiographic characterization and energy spectrum of the IoGold ^{125}I source Model 3631-A/S

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(Received 11 February 1998; accepted for publication 21 December 1998)

Despite the growing popularity of permanent implants using encapsulated ^{125}I seeds, only two types were commercially available, Models 6702 and 6711. Recently, the Food and Drug Administration (FDA) approved a new type of ^{125}I seed, Model 3631-A/S, called IoGold (apparent activity 0.28–0.63 mCi). Due to the large demand for ^{125}I seeds for prostate implants, IoGold seeds will be available in January 1998. In this paper, the basic properties of the IoGold seeds have been evaluated in comparison to the established Models 6702 and 6711. [S0094-2405(99)01003-2]

Key words: brachytherapy, ^{125}I, radiation, dosimetry

The schematic diagram of a new ^{125}I source[1] is shown in Fig. 1. Models 3631-A/S, 6702, and 6711 sources are almost identical in design, and are encapsulated in thin-walled titanium tubes with laser-welded ends. The active component of the IoGold seeds consists of four plastic resin beads impregnated with ^{125}I. Two marker spheres composed of gold and copper are included within the encapsulation to provide radiographic contrast. The main differences between the Model 3631-A/S and Model 6702 seeds is the presence of these two gold–copper marker spheres, and the titanium thickness at the laser-welded end; the end thickness for Model 3631-A/S is 0.15 mm compared to 0.5 mm for the Model 6702 seeds. Therefore, one should expect similar dosimetric properties for these two seed models.

Figure 2 shows an x-ray radiograph of seven Model 3631-A/S seeds and one Model 6711 seed arranged vertically in-line and at the center of a 20 cm thick phantom in one orientation, and another x ray of the same setup but inverted. Different distances between the contrast spheres in individual seeds implies that not all seeds have the same arrangement of contrast spheres and active resin beads as shown in Fig. 1. In addition, there is some leeway inside the titanium tubes because the seeds appear different when inverted. Such clearance is also seen in the Model 6711 seed shown in Fig. 2. Autoradiograms of the same seed arrangement shown in Fig. 3 also indicate that the active spheres and gold–copper markers do not always follow the arrangement shown in Fig. 1. The seed manufacturer, North American Scientific Inc. (NASI) claims that newly implemented quality control procedures will eliminate such seeds from their batches. Autoradiograms of Model 6702 sources (Fig. 4) taken after shaking the seeds show much more uneven distribution of activity within the encapsulation, i.e., there is more space for active spheres to move compared to the IoGold seeds.

The photon energy spectra of Model 3631-A/S and 6702 seeds were measured using a coaxial, high purity germanium (HPGe) detector (Canberra Model GR 1318) operated at −3500 V. A spectroscopy amplifier (Canberra, Model 2022) was used with a shaping time of 4 μs. Finally, a multichannel analyzer (Nuclear Data, Model ND 65) was used to digi-

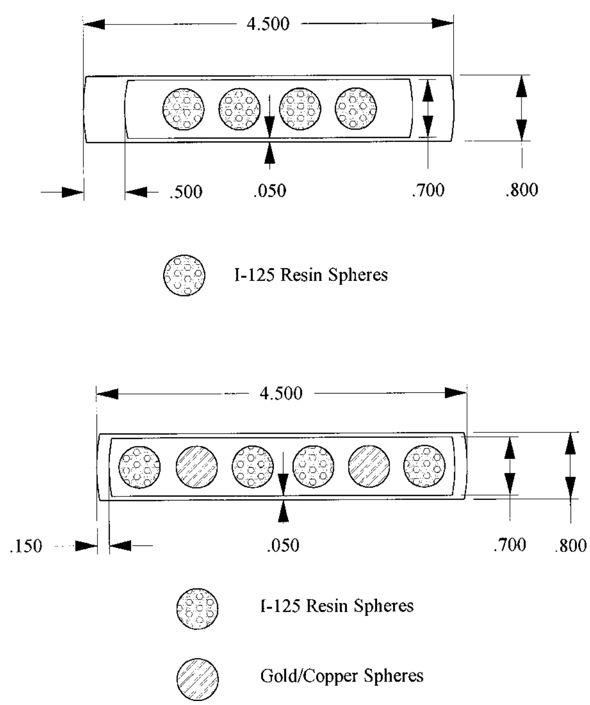

FIG. 1. Schematic diagram of the Model 6702 (top) and Model 3631-A/S (bottom) seeds.

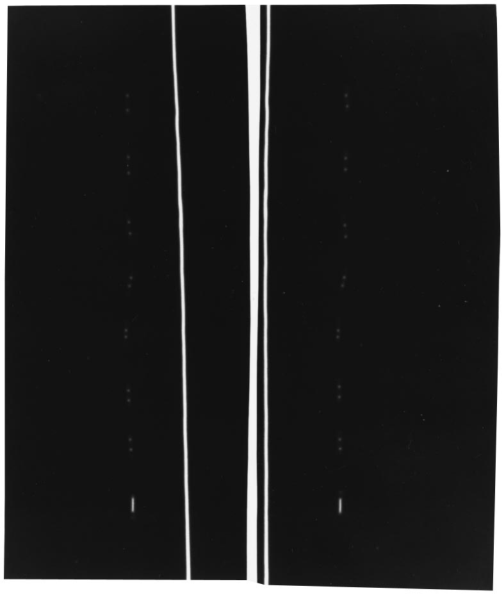

FIG. 2. Radiograms of seven Model 3631-A/S and one Model 6711 iodine seeds arranged in line. The left radiogram was performed with the Model 6711 source long-axis oriented in the vertical direction, the right radiogram was performed with the Model 6711 source long-axis oriented horizontally.

tize the energy signals into 4096 energy bins or channels. Calibration was performed using an ^{241}Am test source which emits photons with energies similar to ^{125}I.

Iodine seeds were placed on a low mass jig at a distance about two meters from the HPGe detector. Spectra were measured at three seed orientations: along the seed axis (0 degrees), at a 15° angle from the seed axis, and at 90° with respect to the seed axis (transverse axis). All three spectra for the Model 3631-A/S and Model 6702 seeds for equal count times are shown in Figs. 5 and 6, respectively. Photon spectra for both seed types consist of the following peaks and intensities (photons per disintegration): 35.5 keV (0.067), 31.9 keV (0.04), 31.0 keV (0.20), 27.5 keV (0.76), and 27.2 keV (0.4).[2] Peaks at 27.5 and 27.2 keV were so close that

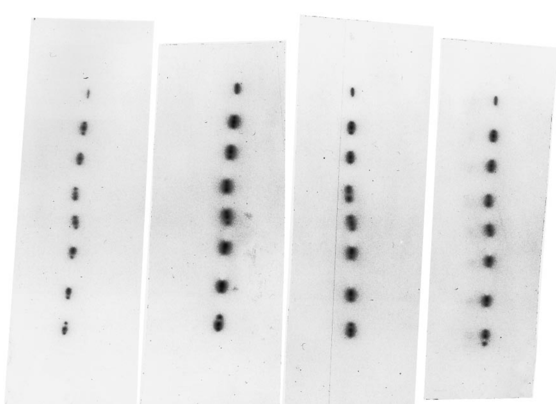

FIG. 3. Autoradiograms of the same as in Fig. 2 seed arrangement. Each film was taken after shaking seeds to move beads inside. Exposure times last a few seconds, and seeds were pressed to the film by hand using an acrylic plate.

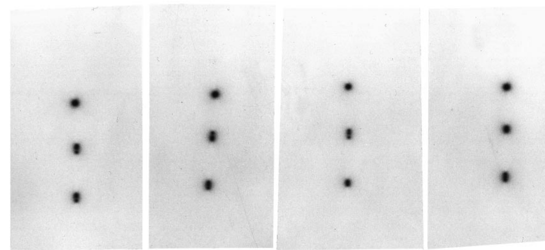

FIG. 4. Autoradiograms of 6702 Model ^{125}I seeds. Each film was taken after shaking the seeds to move the beads inside.

they overlapped and appeared as a single photopeak. The 31.9 and 31.0 keV photopeaks also could not be separately resolved by the HPGe detector, but the bump on the peak indicated its doublet structure.

As expected, spectra for both Model 3631-A/S and Model 6702 seeds at the transverse axis (90 degrees) appeared similar. Spectra measured at 15° have peaks at the same energy but the intensity relative to their own 90° measurements are markedly different. Photons emitted at 15° by 6702 seeds are attenuated by approximately 0.2 mm of titanium [0.05 mm* sin(15°)]. In Model 3631-A/S seeds, photons are attenuated by the same thickness of titanium as well as by the gold/copper markers. In Model 6702 seeds, photons emitted along the seed axis (0°) are attenuated by the relatively thick (0.5 mm) titanium weld. For the Model 3631-A/S seeds, photons emitted at 0° from three of the four resin beads are entirely

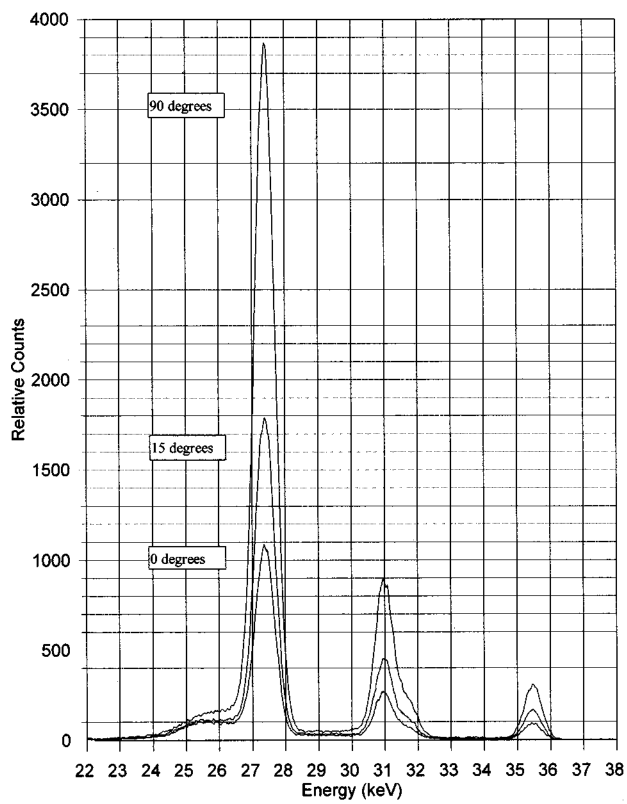

FIG. 5. Photon energy spectra for a Model 3631-A/S seed measured at different angles with respect to the seed long-axis for equal count times.

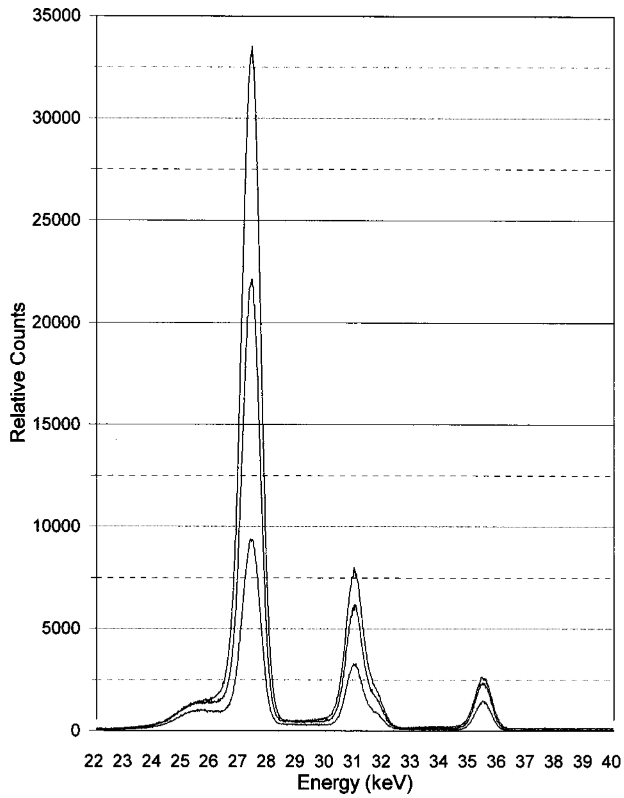

FIG. 6. Energy spectra of photons from a 6702 seed measured at different angles with respect to the seed axis for equal count times.

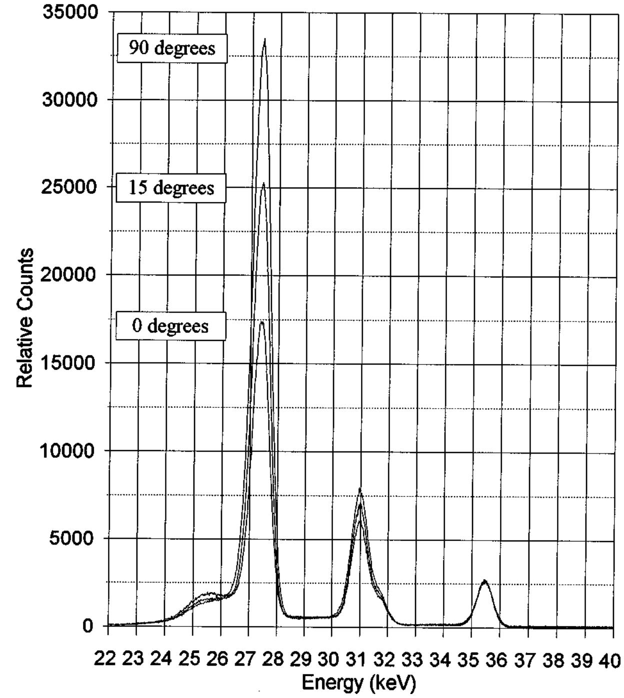

FIG. 8. Energy spectra as in Fig. 6 for Model 6702, but normalized to the 35.5 keV photopeak.

absorbed by gold/copper markers but emissions of the remaining bead are attenuated by the thin, 0.15 mm titanium weld. Therefore, along the 90° transverse axis, Model 3631-A/S and Model 6702 ^{125}I seeds of the same strength emit photons of similar energy spectrum and flux. At 15° and 0°, Model 3631-A/S seeds emit a smaller photon flux than 6702 seeds. But for Model 3631-A/S seeds, the relative attenuation of the different photon energies at 0° and 15° is practically the same as that in the transverse direction (Fig. 7). In contrast, the relative attenuation of the different photon energies of the 6702 photons emitted at 0° and 15° shows a harder spectrum compared to the transverse axis (Fig. 8).

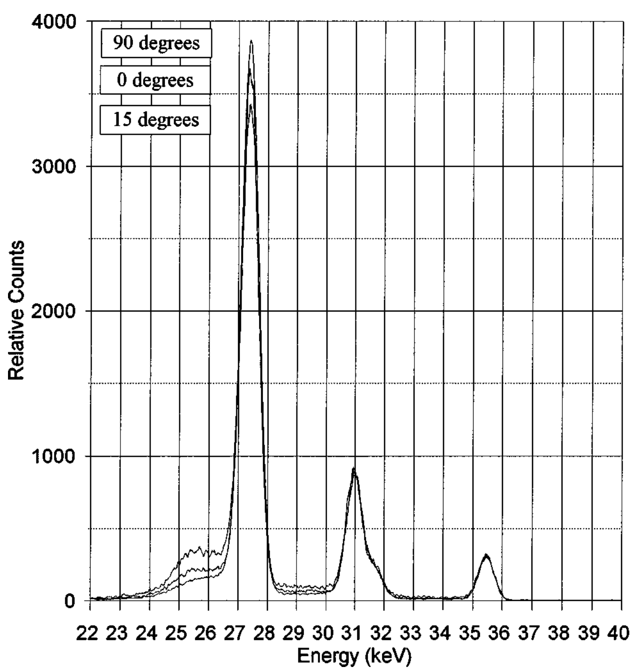

FIG. 7. Energy spectra as in Fig. 5 for Model 3631-A/S, but normalized to the 35.5 keV photopeak.

The first shipment of Model 3631-A/S seeds was accompanied by an individually calibrated seed which was calibrated by direct comparison against a standard source of the same model which has been calibrated by the National Institute of Standards and Technology. We calibrated our customized dose calibrator against this source and measured the activities of all seeds in one batch. According to the Technical Data Sheet supplied by the manufacturer (NASI), this batch contained 30 seeds of apparent activity ranging from 0.305 to 0.330 mCi with average 0.317 mCi. Our measurements[3] have shown good agreement with the manufacturer's values, and ranged from 0.302 to 0.328 mCi with an average activity 0.317 mCi.

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