CHARACTERISTICS OF BRACHYTHERAPY SOURCES USED FOR THE TREATMENT OF PROSTATE CANCER

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BRACHYTHERAPY

- (from the Greek word βραχύς brachys, meaning "short-distance"), is a form of radiotherapy where a sealed radiation source is placed inside or next to the area to be treated.
- is commonly used as an effective treatment for cervical, prostate, breast, and skin cancer and can also be used to treat tumors in many other body sites.
- can be used alone or in combination with other therapies such as surgery, external beam radiotherapy (EBRT) and chemotherapy.

**Interstitial brachytherapy** – radioactive sources are implanted in tissue for the treatment of localized tumors, especially in the prostate. Permanent implant—the seeds remain in the body after the therapeutic effect was delivered, i.e. after radioactive decay is completed.
HISTORY

- $^{222}$Rn, $^{198}$Au and $^{192}$Ir seeds have been used for permanent implants of the prostate in the past.
- In early 1970s, Whitmore et al. developed the technique of open **retropubic implantation of Iodine seeds** administered through needles and guided by a digit in the rectum. The dose and number of seeds required was calculated by estimating the size of the prostate at operation with use of a nomogram and then spacing the implantation needles appropriately.
- Permanent prostate brachytherapy was revolutionalized by the development of the **transrectal ultrasound probe** in the early 1980s.
- With developments in **computer software**, computerized planning has become faster and more efficient making intraoperative planning a practical reality.
Brachytherapy sources

- Permanent implant brachytherapy uses **low energy gamma emitting isotopes** that are encapsulated and can be manufactured to provide a suitable activity.

- $^{125}$ Iodine and $^{103}$ Palladium are the most used sources for the treatment of prostate cancer.

- Due to the increase in the number of patients treated with permanent implant brachytherapy, more sources became available.

- Before use in clinical application, the **dosimetric characteristics** need to be analyzed, both experimentally and theoretically, in concordance with the **AAPM Task Group 43** recommendations.
Air kerma strength is measured and traceable to a primary standard.

The parameters:

- **Dose-rate constant** $\Lambda$, is defined as the dose rate per unit air-kerma strength at a reference point along the transverse axis of the source. This quantity is expressed in units of $\text{cGy h}^{-1}\text{U}^{-1}$, where $U$ is the unit of the air-kerma strength of the source, which is defined as $1\text{U}=1\text{Gy m}^2\text{h}^{-1}$.

- **Radial dose function** $g(r, \theta)$, represents the tissue attenuation of the photons that are emitted by a brachytherapy source.

- **Anisotropy function** $F(r, \theta)$, represents the variation of dose distribution around a brachytherapy source due to the distribution of radioactivity within the source, selfabsorption and oblique filtration of the radiation in the capsule material are measured and related to the primary standard.
Dose rate, $D(r,\theta)$ is defined as:

$$D(r,\theta)=S_k \Lambda \left[ \frac{G_L(r,\theta)}{G_L(r_o,\theta_o)} \right] g_L(r) F(r,\theta) ,$$

where

$D(r,\theta)= \text{dose rate at the point } (r, \theta)$

$S_k = \text{Air-kerma strength for particular source}$

$\Lambda = \text{Dose-rate constant}$

$G_L(r, \theta) = \text{Geometry function}$

$g_X(r) = \text{Radial dose function (the tissue attenuation )}$

$F(r, \theta) = \text{Anisotropy function (variation of dose distribution )}$
Cylindrically symmetrical source

Reference point is chosen to lie on the transverse bisector of the source at a distance of 1cm from its centre i.e. \( r_0 = 1\text{cm} \) and \( \theta_0 = \pi/2 \)
AAPM TG 43

- **Monte Carlo** - calculate the dose rate distribution in water and air
- **Thermoluminescence dosimetry (TLD)**

Dosimetric characteristics:
dose rate constant, radial dose function, \( g(r) \), and anisotropy function, \( F(r, \theta) \) are measured in Solid Water® using LiF TLD chips. These measurements were performed following the AAPM TG-43 task group recommendation.
Experimental setup for measurement of the radial dose function and dose rate constant with LiF TLDs.

Schematic diagram of the Solid Water phantom design for TLD measurements of the anisotropy functions, $F(r, \theta)$.
125 Iodine

- Average energy ~28keV
- Iodine-125 isotope has a half-life of 59.46 days.
- It decays as a result of electron capture by the radiation of X-rays and $\gamma$ radiation in the energy range up to 35 keV. The electrons emitted during this decay are absorbed by the titanium capsule material.
- Dose distribution around the seed is highly anisotropic due to titanium end welds.

$^{125}$I is reactor-produced radionuclide and is available in large quantities. Its production follows the reaction:

$^{124}$Xe ($n,\gamma$)$\rightarrow ^{125m}$Xe(57s)$\rightarrow ^{125}$I (59,4 d)

$^{124}$Xe ($n,\gamma$)$\rightarrow ^{125g}$Xe(19,9h)$\rightarrow ^{125}$I (59,4 d)
IsoSeed® I-125 (I25.S06)

(Eckert & Ziegler BEBIG, Germany)

IsoSeed® I-125 contains a cylindrical-shaped ceramic saturated with a radioactive iodine-125 compound, which is enclosed by a laser-sealed titanium tube. Gold wire inside the ceramic is used as an X-ray marker.

The dose rate constant depends on the type of the source, for IsoSeeds® I-125 the dose rate constant is 1.033 cGy h⁻¹ U⁻¹. Is produced in the range of 0.2-0.9mCi
The core consists of a cylindrical molybdenum marker. This is coated with a 3 \( \mu \text{m} \) thick nickel followed by a pure silver layer of 25 \( \mu \text{m} \) thickness with a radioactive 125I layer of 2 \( \mu \text{m} \) thickness in the form of silver iodide. The radioactive element is encapsulated in a hollow titanium tube. The tube is sealed by laser welding of hemispherically shaped ends.
IsoSeed I25.S17plus
(Eckert & Ziegler BEBIG, Germany)

- has been designed to essentially replace the molybdenum marker with a silver one in the IsoSeed I25.S17 model.
- The I25.S06 source delivers greater dose than I25.S17plus
OncoSeed $^{125}$I Model 6711
Amersham, UK

The 6711 source consists of a beveled right circular cylinder of silver coated with a radioactive layer and encased inside a cylindrically symmetric titanium shell. The radioactive layer consists of a mixture of AgBr and AgI present in a 2.5:1 molecular ratio.
Amersham 6702 and 6711

- Model **6702** source consists of three resin spheres (resin density is 1.2 g/cm³ and has a molecular composition of C_{12}H_{18}NCl), each with diameter of 0.600 mm. The spheres are coated with ¹²⁵I and encapsulated in a titanium tube with 0.050 mm thick walls and an outer diameter of 0.800 mm.

- The overall length is 4.50 mm and the active length is 3.30 mm (calculated using the TG-43 effective line source length with a seed spacing of 1.10 mm and N=3 sources). The maximum possible displacement of a source sphere from its nominal position is 1.45 mm along the seed axis and 0.050 mm in the radial direction.

- Model 6711 contains up to 5.5 mCi of ¹²⁵I absorbed on a silver wire radiographic marker. Show up clearly as lines in a radiograph.
- a physical length of 5 mm and an outer diameter of 0.8 mm.
- was manufactured using a 3.8 mm long by 0.25 mm diameter tungsten rod, coated with a 0.1 mm thick organic matrix containing 125I, encapsulated in double titanium capsules.
- Laser welding seals the two capsules. The double encapsulation is designed to provide thinner walls at the ends of the source, relative to other sources, such as the Model 6711.
- This design will improve the anisotropy function near the ends of the source. The improvement is due to less self-absorption at the end of the source due to the lesser thickness.
- activities ranging from 0.2 up to 10 mCi.
MED3631-A/S North American Scientific, Incorporated, North Hollywood, California that has become available for use in interstitial brachytherapy applications. This source has since been reconfigured with the intent of providing greater facility for radiographic source identification while achieving a better approximation to the isotropic point.
IsoAid designed the Model IAI-125 source with a physical length of 4.5 mm and outer diameter of 0.8 mm. To fabricate this source, the 125I isotope was adsorbed ~0.001 mm thick coating of AgI on the surface of a 3 mm long and 0.5 mm diameter silver rod, which was then encapsulated in a 0.05 mm thick titanium capsule. The silver rod serves as a x-ray marker. An active length of 3 mm was assumed for this source during the calculations of the geometric functions.

Fig. 1. Schematic diagram of the ADVANTAGE™ ¹²⁵I, Model IAI-125, brachytherapy source (Courtesy of IsoAid LLC). The area between the capsule and x-ray marker is filled with air.
EchoSeed™ model 6733 125I brachytherapy source (Amersham, UK)

This design enhances the visualization of the seeds for interstitial prostate implants. The external surface of this source has several circular grooves, which improves the ultrasound signature of the source over a wider range of angular orientation.

The source was manufactured by placing a 3.0 mm long and 0.5 mm diameter silver cylinder coated with 125I inside a titanium tube with walls 0.05 mm thick. The outer capsule is “threaded” like a screw with 6 “threads.” The two ends of the outer cylindrical tube are laser welded. The source is available in activities of 0.2 mCi to 5.0 mCi.

Calculated and measured radial dose functions of the EchoSeed™ Model 6733 125I Brachytherapy Source, in Solid Water [5]
InterSource125 Iodine brachytherapy source

(International Brachytherapy, Inc. USA)

Three active insoluble organic matrix bands containing 125I and an X-ray marker (platinum/iridium alloy) are placed in between two titanium tubes with laser welded ends. The inner and outer walls of the source are 0.04mm thick. The relative composition of the organic matrix was 85.7% carbon and 14.3% hydrogen with a density of 1.0 g/cm³.
Comparison of the dose rate constant for Iodine 125 brachytherapy sources

<table>
<thead>
<tr>
<th>Source model</th>
<th>Method</th>
<th>Medium</th>
<th>Dose rate constant cGy/h/U</th>
</tr>
</thead>
<tbody>
<tr>
<td>EchoSeed 125I</td>
<td>measurement</td>
<td>Solid Water</td>
<td>0.95±8%</td>
</tr>
<tr>
<td></td>
<td>measured</td>
<td>water</td>
<td>0.99±8%</td>
</tr>
<tr>
<td></td>
<td>Monte Carlo simulation</td>
<td>Solid Water</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td>Monte Carlo simulation</td>
<td>water</td>
<td>0.97</td>
</tr>
<tr>
<td>Best I-125</td>
<td>measurement</td>
<td>Solid Water</td>
<td>0.961±6.8%</td>
</tr>
<tr>
<td></td>
<td>measured</td>
<td>water</td>
<td>1.01±6.8%</td>
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<tr>
<td>model 6711</td>
<td>Monte Carlo simulation</td>
<td>Solid Water</td>
<td>0.934</td>
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<tr>
<td></td>
<td>Monte Carlo simulation</td>
<td>water</td>
<td>0.973</td>
</tr>
<tr>
<td>model 6702</td>
<td>Monte Carlo simulation</td>
<td>Solid Water</td>
<td>0.998</td>
</tr>
<tr>
<td></td>
<td>Monte Carlo simulation</td>
<td>water</td>
<td>1.03</td>
</tr>
<tr>
<td>model 2300</td>
<td>measurement</td>
<td>Solid Water</td>
<td>0.955±3%</td>
</tr>
<tr>
<td>MED 3631</td>
<td>measured</td>
<td>water</td>
<td>1.06±5%</td>
</tr>
<tr>
<td>InterSource 125I</td>
<td>Monte Carlo simulation</td>
<td>water</td>
<td>1.03</td>
</tr>
<tr>
<td>IAI125</td>
<td>measurement</td>
<td>Solid Water</td>
<td>0.99±0.08</td>
</tr>
<tr>
<td></td>
<td>Monte Carlo</td>
<td>Solid Water</td>
<td>0.95±0.03</td>
</tr>
<tr>
<td></td>
<td>Monte Carlo</td>
<td>water</td>
<td>0.98±0.03</td>
</tr>
<tr>
<td>I125.S17</td>
<td>measured</td>
<td>Solid Water</td>
<td>0.951</td>
</tr>
<tr>
<td></td>
<td>Monte Carlo</td>
<td>0.929</td>
<td></td>
</tr>
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</table>
Comparare funcție radială pentru diverse surse.

Fig. 5. Funcții de doză radială pentru sursele Model 2300 (trunchi cu pătrate), Model 6702 (circulare), și Model 6711 (triunghiulare).

Fig. 3. Compărație a funcțiilor de doză radială măsurate pentru sursele Best+125I de terapie bărbcăroasă în Solid Water™ în comparație cu alte surse comercialmente disponibile. Linea solidă reprezintă un ajustament polinomial de ordin 4 la datele măsurate. Erorile de măsurare sunt indicate cu +5%.

Fig. 2. Comparare a funcțiilor de doză radială în apă, g(r), pentru markerul central MED3631-A/M, MED3631-A/S, și modelul 6702 de terapie bărbcăroasă.
Comparare funcție anizotropica pentru diverse surse

Fig. 8. Comparare a funcției de anisotropie a sursei InterSource^{125} la 5 cm de la model 6711, Model 6702, NAS/Mentor IoGold, și Best^{10, 123}. Linia solidă reprezintă o 4-a ordină polinom de la munca prezentă.

Fig. 4. Comparare a funcției de anisotropie a sursei 6733^{125} la 5 cm de la model 6711, IoGold, și Best^{10, 123}. Linia solidă reprezintă o 4-a ordină polinom pentru munca prezentă.

Fig. 6. Comparare a funcției de anisotropie de Monte Carlo calculată a sursei Model IAI-125 de la un alt surse comerciale disponibile. Linia solidă reprezintă o 4-a ordină polinom de la sursa Model IAI-125. Linia subțire reprezintă o 4-a ordină polinom de la IoGold sursele, pentru a învingea câitori. Erorile pe sursele pentru Model IAI-125 sînt ±3%.
Comparare functie anizotropica pentru diverse surse

**Fig. 9.** Anisotropy functions for $^{125}$I source, Model 2300 (left panel), Model 6711 (middle panel), and Model 6702 (right panel) at radial distances of 1 cm (circles), 2 cm (triangles), 3 cm (squares), 4 cm (inverted triangles), and 5 cm (diamonds).

**Fig. 3.** Anisotropy function values of this work for the new $^{125}$I plus (solid line) and the 6711 source (broken line) plotted as a function of polar angle $\theta$ at radial distances $r = 0.5$ cm (left) and $r = 1$ cm (right). Corresponding results of Lymeropoulos et al. [2] for the $^{125}$I source (crosses) and consensus data [5] (circle) as well as results of Taylor and Rogers [7] (square) for the 6711 source are also presented for comparison.

**Fig. 5.** A comparison of the measured anisotropy functions, $P(r, \theta)$, of the Becton $^{125}$I brachytherapy source in Solid Water™ at distances of 2 cm ([a] upper panel) and 5 cm ([b] lower panel) from the source center with other commercially available sources. The solid line represents a fourth-order polynomial fit to the measured data for the Becton $^{125}$I source. The dashed lines are connected data points for other data. The error bars represent $\pm 5\%$. 
Fig. 3. Anisotropy function $F(r, \theta)$, measured for the MED3631-A/M source compared to those for the MED3631-A/S source and the models 6702 and 6711 seeds at radii of 1, 3, and 5 cm vs angle between the source axis and the measurement point, in (a), (b), and (c), respectively.
Palladium 103

- Palladium-103 may be created from palladium-102 or from Rhodium-103 using a Cyclotron. Palladium-103 has a half-life of 16.99 days and decays by electron capture to rhodium-103, emitting gamma-rays with 21 keV of energy.
- Due to self absorption, it is highly anisotropic
- Provide a biologic advantage in permanent implants due to much faster dose rate
Best® 103Pd source.  Best Medical International, USA

The source has a physical length of 5 mm, an outer diameter of 0.8 mm. This source was manufactured by placing three 103Pd-coated **spherical polymer** ~composition by weight percent: C: 89.73%, H: 7.85%, O: 1.68%, and N: 0.74% beads on either side of a centrally located 1.2 mm long tungsten marker inside a double wall titanium capsule.

The total wall thickness of this source is 0.08 mm in each direction. The rim of the outer capsule was laser welded on the wall of the inner capsule. The source is available with activities ranging from 0.2 to 2.0 mCi.
Theragenics TheraSeed® Model 200 103Pd interstitial brachytherapy seed (Theragenics Corporation)

The source is encapsulated within a 0.056 mm thick titanium tube with a measured external length of 4.50 mm and average. The tube ends are closed by means of inverted “end cups” composed of 0.040 mm thick Ti metal welded to the Ti tube.

The internal source components include two graphite pellets modeled as right circular cylinders with 0.56 mm diams and 0.89 mm lengths! upon which a mixture of radioactive and nonradioactive palladium is added. A lead marker separates the graphite pellets.

The light seed pellets, representative of the current manufacturing process using accelerator produced 103Pd, are assumed in this study to have a 2.2 mm thick Pd coating ~57 μ g/pellet. The heavy seed pellets, carrying reactor-produced 103Pd, were assumed to have a 10.5 mm ~260 μ g/pellet thick coating of Pd metal.
InterSource103 palladium brachytherapy source  International Brachytherapy Inc., IBt, Belgium

The source has an effective active length of 3.7 mm, an outer dimension of 4.5 mm in length and a diameter of 0.81 mm. The active length of the source was determined from the distances between the outer edges of the two outer bands. This source was manufactured placing a 0.045 mm thick platinum/iridium alloy ~90% platinum and 10% iridium x-ray marker and three cylindrical bands of an insoluble organic matrix containing palladium between two hollow titanium cylindrical tubes. The edges of the two cylindrical tubes were laser welded. The inner and outer walls of the source are each 0.04 mm in thickness. The relative composition by weight of the organic matrix was 85.7% carbon and 14.3% hydrogen with a density of 1.0 g/cc. This source is available from International Brachytherapy Inc. in the activity range of 0.5 mCi to 2.0 mCi.
The new source design encapsulation is similar to those of existing 125I seed models MED3631-A/M ~North American Scientific, Inc., Chatsworth, California!, 6702 and 6711 ~Nycomed-Amersham, Arlington Heights, Illinois. Nominal external dimensions are identical to these other seeds. Internally, the radioactive elements are of type and dimension similar to those in the model 6702, but with two gold-copper binary alloy markers added. The new design, MED3633, 103Pd source has the same internal and external configuration as the MED3631-A/M 125I source. In this design, the two markers are flanked by two active elements at each end of the source. The central marker design loads the source ends to provide a more isotropic dose distribution.
Comparison of the dose rate constant for Palladium 103 brachytherapy sources

<table>
<thead>
<tr>
<th>Source model</th>
<th>Method</th>
<th>Medium</th>
<th>Dose rate constant cGy/h/U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best 103 Pd</td>
<td>measurement</td>
<td>Solid Water</td>
<td>0.67±8%</td>
</tr>
<tr>
<td></td>
<td>measurement</td>
<td>water</td>
<td>0.69±8%</td>
</tr>
<tr>
<td></td>
<td>Monte Carlo simulation</td>
<td>Solid Water</td>
<td>0.65±3%</td>
</tr>
<tr>
<td></td>
<td>Monte Carlo simulation</td>
<td>water</td>
<td>0.67±3%</td>
</tr>
<tr>
<td>model 200</td>
<td>measurement</td>
<td>Solid Water</td>
<td>0.65±8%</td>
</tr>
<tr>
<td></td>
<td>Monte Carlo simulation</td>
<td>water</td>
<td>0.68±3%</td>
</tr>
<tr>
<td>MED 3633</td>
<td>measurement</td>
<td>water</td>
<td>0.68±5%</td>
</tr>
<tr>
<td>InterSource</td>
<td>measurement</td>
<td>Solid Water</td>
<td>0.664±5%</td>
</tr>
<tr>
<td></td>
<td>Monte Carlo simulation</td>
<td>Solid Water</td>
<td>0.660±3%</td>
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<tr>
<td></td>
<td>Monte Carlo simulation</td>
<td>water</td>
<td>0.696±3%</td>
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</table>
Fig. 3. Anisotropy function measured, $F(r, \theta)$, for the MED3633 source compared to that for the model 200 source at radii of 1, 3, and 5 cm versus angle between the source axis and the measurement point in Figs. 3(a)–3(c), respectively.

Fig. 5. Comparison of the Monte Carlo calculated radial dose function of the InterSource\textsuperscript{103} palladium source in water with radial dose function of Model 200\textsuperscript{110} Pd (Refs. 12 and 13) and MED 3633 PdGold (Ref. 14). The solid line is connecting the data points.

Fig. 8. Comparison of the Monte Carlo calculated anisotropy functions of the InterSource\textsuperscript{103} palladium source with Model 200 (Ref. 13) and MED3633 PdGold (Ref. 14). These anisotropy functions are in water at distances of 2 cm (upper panel) and 5 cm (lower panel) from the source center. The solid line is connecting the data points.
IRIDIUM 192 (¹⁹²Ir)

- Produced in Nuclear reactors.
- T½ = 73.8 days
- Decays through β emission and electron capture to ¹⁹²Pt and ¹⁹²Osmium
- Decay scheme: ¹⁹²Ir → ¹⁹²Pt + ⁰⁻₁e + γ
- Emits 11 γ rays of energies ranging from 0.136 to 0.613 MeV
- Effective γ rays energy is appr. 0.380 MeV
- Emits β particles max energy 0.670 MeV
- β filtration = 0.1mm of platinum
- (Eliminated by stainless steel capsule)
- HVT- 4.5mm of Lead (Pb)
Ir-192

- The high specific activity of Ir-192 (~9000Ci/g) makes it an attractive source for use with high dose rates (HDR) are required.

<table>
<thead>
<tr>
<th></th>
<th>MicroSelectron &quot;Classic design&quot;</th>
<th>MicroSelectron &quot;New design&quot;</th>
<th>GammaMed 12i HDR</th>
<th>GammaMed Plus HDR 0.9 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active length [mm]</td>
<td>3.5</td>
<td>3.6</td>
<td>3.5</td>
<td>3.5</td>
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<tr>
<td>Active diameter [mm]</td>
<td>0.6</td>
<td>0.65</td>
<td>0.6</td>
<td>0.6</td>
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<tr>
<td>Total diameter [mm]</td>
<td>1.1</td>
<td>0.9</td>
<td>1.1</td>
<td>0.9</td>
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<tr>
<td>Encapsulation</td>
<td>stainless steel</td>
<td>stainless steel</td>
<td>stainless steel</td>
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<tr>
<td>Manufacturer</td>
<td>Nucletron</td>
<td>Nucletron</td>
<td>MDS Nordion</td>
<td>MDS Nordion</td>
</tr>
</tbody>
</table>

Stiff drive cable  flexible cable  $^{192}\text{Ir}$ source 0.9 mm dia.
Comparison of dose rate constants values ($\Lambda$) for 192Ir seed and wire sources

<table>
<thead>
<tr>
<th>Reference</th>
<th>Source</th>
<th>Phantom</th>
<th>Method</th>
<th>Dose rate constant ($\Lambda$) cGy h$^{-1}$ U$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Williamson (1991)</td>
<td>$^{192}$Ir-seed 3 mm</td>
<td>Water</td>
<td>Monte Carlo</td>
<td>1.11 ± 0.002</td>
</tr>
<tr>
<td>Williamson (1991)</td>
<td>$^{192}$Ir-seed 3 mm</td>
<td>Solidwater</td>
<td>TLD</td>
<td>1.121 ± 0.003</td>
</tr>
<tr>
<td>Nath et al. (1990a)</td>
<td>$^{192}$Ir-seed 3 mm</td>
<td>Solidwater</td>
<td>TLD</td>
<td>1.09 ± 0.03</td>
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<tr>
<td>Weaver et al. (1989)</td>
<td>$^{192}$Ir-seed 3 mm</td>
<td>Solidwater</td>
<td>TLD</td>
<td>1.111 ± 0.015</td>
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<tr>
<td>Chiu-Tsao et al. (1990)</td>
<td>$^{192}$Ir-seed 3 mm</td>
<td>Solidwater</td>
<td>TLD</td>
<td>1.11</td>
</tr>
<tr>
<td>Meigooni et al. (1997)</td>
<td>Varisource wire, 10 mm</td>
<td>Solidwater</td>
<td>TLD</td>
<td>1.084 ± 0.040</td>
</tr>
<tr>
<td>M. Ghiassi-Nejad</td>
<td>$^{192}$Ir-seed 5 mm</td>
<td>Plexiglass</td>
<td>TLD</td>
<td>1.196 ± 0.060</td>
</tr>
<tr>
<td>M. Ghiassi-Nejad</td>
<td>$^{192}$Ir-wire 10 mm</td>
<td>Plexiglass</td>
<td>TLD</td>
<td>1.082 ± 0.054</td>
</tr>
</tbody>
</table>

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**Fig. 4.** The anisotropy function obtained at different angles between 0 and 360° at a distance of 1 cm for $^{192}$Ir sources: (♦) seed and (○) wire.
Conclusions

- Dosimetric data are comparable between the available sources used for implant.
- The difference are given by the physical properties: wall thickness, radioactive material carrier, radio-opaque markers.
- The new sources are made to reduce the anisotropy and to be better visible on radiographs.
REFERENCES


Report on the dosimetry of a new design 125Iodine brachytherapy source Robert E. Wallace and Jay J. Fan Med. Phys. 26, 1925 (1999);


G. Lymperopoulou, G. Papagiannis, L. SakelliouMonte Carlo and thermoluminescence dosimetry of the new IsoSeed®model I25.S17 I25 interstitial brachytherapy seed


