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PROSTATE BRACHYTHERAPY WITH IODINE-125 SEEDS: RADIATION PROTECTION ISSUES

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Aims and background: **Brachytherapy for prostate cancer by means of permanently implanted ^{125}I sources is a well established procedure. An increasing number of patients all over the world are treated with this modality. When the technique was introduced at our institution, radiation protection issues relative to this technique were investigated in order to comply with international recommendations and national regulations. Particular attention was paid to the need for patient shielding after discharge from hospital.**
Methods: **The effective and equivalent doses to personnel related to implantation, the effective dose to patient relatives as computed by a developed algorithm, the air kerma strength values for the radioactive sources certified by the manufacturer compared with those measured by a well chamber, and the effectiveness of lead gloves in shielding the hands were evaluated.**
Results: **The effective dose to the bodies of personnel protected by a lead apron proved to be negligible. The mean equivalent doses to the physician's hands was 420 µSv for one implant; the technician's hands received 65 µSv. The mean air kerma rate measured at the anterior skin surface of the patient who had received an implant was 55 µGy/h (range, 10-115) and was negligible with lead protection. The measured and certified air kerma strength for ^{125}I seeds in RAPID Strand corresponded within a margin of ± 5%. The measured attenuation by lead gloves in operative conditions was about 80%. We also defined the recommendations to be given to the patient at discharge.**
Conclusions: **The exposure risks related to brachytherapy with ^{125}I to operators and public are limited. However, alternation of operators should be considered to minimize exposure. Patient-related measurements should verify the dose rate around the patient to evaluate the need for shielding and to define appropriate radiation protection recommendations.**

Key words: permanent prostate brachytherapy, radiation safety, ^{125}I seeds.

Introduction

Sixty patients affected by prostate adenocarcinoma received implants with ^{125}I seeds at the Radiotherapy Department of the University in Turin between 2000 and 2004. The aim of such treatment is the delivery of a high and highly uniform localized radiation dose to the prostate gland, preserving the urethra and the anterior rectum wall in selected patients, in accordance with international recommendations[1,2]. The prescribed dose, referred to as "minimum peripheral dose", is 145 Gy for monotherapy treatments. The medical personnel is exposed to radiation and so is the population when the patient is discharged from hospital. Compliance with the ALARA principle as well as national regulations is important here.

In this study we assessed the equivalent and effective doses to personnel and population. Special attention was paid to individuals assisting the patient after discharge from hospital, so that appropriate radiation protection advice could be given. Air kerma rates at the anterior skin surface of the patient and at 1 meter distance were measured with and without personal shielding. We developed a specific algorithm to evaluate the time interval during which the patient should wear protection. Assessments were performed relative to unusual events (accidents, surgical intervention, death, autopsy and cremation). The certified and measured values of the air kerma strength of the RAPID Strand were compared. In addition, the shielding properties of protective lead gloves were experimentally evaluated.

Material and methods

Implantation

The radiotherapy staff at our institute is composed of a radiation oncologist and a urologist (implantation), an anesthesiologist, a radiation therapist (seed preparation), a medical physicist (treatment planning, technical assistance and radiation protection aspects) and nurses. We use a standard implantation procedure that has been described in many papers[1,2].

After implantation the absence of sources on working surfaces, inside used needles and on surgical material is checked by means of a highly sensitive detector (NaI scintillator crystal Ludlum, 25 mm diameter, 25 mm thick). Lead aprons are used to minimize the radiation dose to personnel. Staff wear personal dosimeters to measure the dose to the whole body; in addition, operators manipulating sources wear finger and wrist thermoluminescent dosimeters to measure doses to the extremities.

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Sources

The radioactive sources used for implantation are ^{125}I seeds, Model 6711 (RAPID Strand, Nycomed Amersham, Little Chalfont, Buckinghamshire, England). Each RAPID Strand consists of 10 seeds embedded in stiffened suture. The physical characteristics of ^{125}I and a description of model 6711 can be found in the literature[3,4]. The iodine sources implanted at our institution have a nominal seed strength (mean) of 0.46 U (0.361 mCi). The total implanted air kerma strength ranges from 19 U to 52 U (15 to 41 mCi) depending on the prostate volume.

On arrival, the radioactive seeds are housed in a plastic jig within a stainless steel shielding tube inside sterile packaging. The measured air kerma rate around the tubes is negligible. Each seed is a welded titanium capsule containing a silver rod with resin onto which ^{125}I has been absorbed. The radiation output is expressed as air kerma strength (U), but for historical reasons the seed strength is also given in terms of "apparent (equivalent) activity" in units of mCi.

The documentation certifies air kerma strength and apparent activity values with a relative uncertainty estimated to be ± 7%. As the radiation output on the implantation day is the input data for calculation of treatment planning, a check should be performed. TG64 recommends that at least 10% of the seeds be calibrated before use and compared with the certificate before use[3]. To verify seed calibration, a well-type ionization chamber (HDR1000 Plus, Standard Imaging, Middleton, Wisconsin) was used[4,5]. A sterilizable insert described by Butler *et al*.[5] may be used for this purpose.

The chamber was calibrated by an ADCL standard (Department of Medical Physics, University of Wisconsin) for the specific source model used. The uncertainty in calibration of the well chamber is between ± 2.5% and ± 0.2% (for charge measures) or 0.3% (for current measures) for the electrometer. The air kerma strength of a source may be obtained from a charge or a current value. Measurements of a single seed or a RAPID Strand (10 seeds) were performed.

To reduce the radiation dose absorbed by the hands, lead gloves should be used. The attenuation of lead gloves (0.3 mm nominal thickness, declared attenuation of about 57% at 60 kV_p) was evaluated using a TOL/F LB 132 ionization chamber (Berthold, Bad Wildbad, Germany) with a photon energy range from 10 keV to 7 MeV.

Patient care and discharge

After implantation of the seeds the patient remains in the controlled area for 24 to 48 hours and is then discharged with specific radiation precaution instructions, documentation about the radiation sources and implanted activity, and instructions to his relatives.

The patient may receive visitors and regular nursing care. These people wear a lead apron during contact with the patient. Urine is collected and stored in a restricted area and the containers are checked before disposal to verify the absence of seeds. The bed linen and room floor are also checked after patient discharge. A high-sensitivity scintillation detector is used (Ludlum model 3 survey meter) to detect any single seed. The air kerma rate at the patient's skin surface and at 1 meter distance in front of the patient is measured by a TOL/F ionization chamber. Readings are provided in real time.

An algorithm has been defined that allows to determine the time interval the patient should wear shielding (lead apron of 0.25 mm Pb equivalent) according to the annual dose limits to the population; it is based on the measured air kerma rate at 1 meter from the anterior surface of the patient.

The effective dose D to people at any distance from the patient, integrated on a selected time interval, is given by the sum of the accumulated dose with protection and the accumulated dose without shielding. From this value the time interval can be obtained after which the patient may remove the shielding while respecting the population dose limits.

The new effective dose limits recently introduced by Italian regulations (art. 4, D.Lgs 187/00) relative to people assisting the patient (family) should also be taken into account in the computation:

a) adults aged <60 years: 3 mSv;
b) adults aged >60 years: 10 mSv.

It must be mentioned here that the only study available in the literature about direct dose monitoring of family and household members reports very low values (calculated mean lifetime dose to a wife ranging from 0.04 to 0.55 mSv)[10]. Instructions relative to the use of personal shielding are elaborated for each patient individually depending on the implanted activity, measured air kerma rate around the patient, and living conditions (working activity, presence of children or pregnant women, etc.). The prescribed time interval will be indicated in the documentation given to the patient.

The patient is advised of the possibility that in the course of treatment one or more seeds might become detached. He is therefore instructed to filter his urine for a few days after discharge to intercept seeds. It appears from the literature that there is no agreement about the period of time the patient should filter his urine or even on the necessity of filtering[3]. At discharge the patient receives oral and written instructions and documentation about the implant.

Accidental events may entail a risk to people or the environment. In such cases special procedures have been established in accordance with international recommendations[10].

Surgical intervention and death

Surgical intervention should be delayed as much as possible to benefit from radioactive decay. When surgery is performed, the tissues containing the implant should be identified to minimize contact. Protective lead gloves and long-handled forceps should be used. Operators should be monitored with appropriate personal dosimeters.

If the patient dies, Italian law (art. 108 DPR 285, 10 September 1990) requires details about implantation

such as brachytherapy date, radioisotope used and radiation activity to be reported in the death certificate. The radiation oncologist and radiation protection supervisor give instructions to personnel to minimize the risk of exposure. Instructions should be specific, taking into account the residual activity, and may include removal of the organ with the radioactive implant, the kind of shielding to be used, and body identification by a tag.

If an autopsy is performed, the air kerma rate in the specific situation should be estimated to determine the maximum time interval allowed to the pathologist without exceeding the dose limits to the body and extremities. Recommendations about alternation of operators should be given. Implant removal using long-handled forceps and protective gloves prior to autopsy is advisable. The removed organ should be put in a shielded box and disposed of according to the pertinent regulations.

In case of cremation precautions should be taken if the body is to be cremated less than 20 months, ie 10 half-lives, from the date of the implant[6,11]. In this case the process could expose the operator to inhalation or ingestion of radioactive material resulting in a radiation dose of 1 mSv. The operator is advised to wear a mask and rubber gloves, to store the cremated remains in a metal box, and to wait 20 months before dispersion.

Results

The reported data refer to 60 ^{125}I implantations. Implanted seeds, their apparent activity, prostate volumes evaluated before and on the implantation day and air kerma rates measured at the anterior skin surface and at 1 meter distance are listed in Table 1.

Measurements on the patient

The air kerma rate values measured on the patient vary widely, as reported by many authors[9,12]. A mean value of 55 µGy/h at the anterior skin surface of the patient and 1 µGy/h at 1 meter distance in front of the patient was found; the dose measured in the lateral direction was proportionally lower.

Table 1 - Statistics about 60 implants: implanted seeds, total apparent activity, prostate volumes estimated by ultrasonography, measured air kerma rate at the anterior and lateral skin surface and at 1 meter from the patient

Characteristics	Mean	Minimum	Maximum
Number of seeds	75	41	129
Total implanted activity (MBq)	969	548	1509
Previsional volume (cm^3)	32	17	58
PTV volume (cm^3)	30	15	67
Air kerma rate close to the patient, anterior (µGy/h)	55	10	115
Air kerma rate at 1 meter, anterior (µGy/h)	1	0.5	4
Air kerma rate close to the patient, lateral (µGy/h)	2.7	0.7	9
Air kerma rate at 1 meter, lateral (µGy/h)	0.5	n.r.	1.2

It could be assumed that not only the radiation activity but also a different thickness and nature of the interposed tissue as well as the arrangement of the seeds determine the air kerma rate from the patient. We therefore conclude that a realistic estimate of doses to operators and population should be based on direct measurements on each patient who has received an implant.

Personal dosimetry

Personal dosimetry is used to measure the effective and equivalent doses to radiation oncologists, urologists, nurses and radiation therapists. The fluoroscopy time used to check the position of the seeds is variable, the differences being mainly due to the operator's experience.

In Table 2 the equivalent and effective mean dose values relative to the physician and radiation therapist are reported as $H_p(0.07)$ and $H_p(10)$. The doses were measured with film badge and thermoluminescent finger and wrist dosimeters; the highest values recorded are reported. The physician performing implantation and the radiation therapist preparing the seeds receive a low dose to the whole body as they are shielded by a lead apron and protective lead glass.

The hands receive a higher dose. Lead gloves are not routinely used because they reduce the tactile sensibility. Measurements of transmitted radiation by means of an ionization chamber show an attenuation of about 80%. The use of lead gloves reduces the dose to the hands and should be encouraged especially where alternations of operators is not possible and when the use of fluoroscopy is frequent. The physician's hands receive higher doses than those of the radiation therapist. This is probably due to the use of fluoroscopy during implantation in addition to the exposure to radioactive material. A reduction of about 50% in the received doses was observed between the first and second year of work due to increased experience resulting in reduced implantation time and fluoroscopy use.

Quality control of seed activity

For calibration of the seeds a series of checks were performed in which the actual activity was compared with the certified values. The air kerma rates measured with the ionization well chamber agreed with the reference values with a ±5% margin.

Table 2 - Mean equivalent and effective dose values to personnel for one implantation, reported as Hp(0.07) and Hp(10)

Characteristics	µSv
Effective dose to physician, $H_p(10)$	30
Equivalent dose to physician, $H_p(0.07)$	420
Effective dose to technician, $H_p(10)$	<2
Equivalent dose to technician, $H_p(0.07)$	65

Dose to the population

We observed that the mean air kerma rate at the anterior skin surface of the patient (55 μGy/h) was in agreement with those reported by other authors (Table 3)[12]. Using the described algorithm and with a very conservative assumption (an entire day spent at 1 m from the patient), we found that the patient should wear protection when the measured air kerma rate at 1 meter is ≥2 μGy/h. In a more realistic situation (12 hours spent at 2 m from the patient) no lead apron is needed. Guidance on minimizing exposure time and close conctact is necessary to reduce the dose to the population[1].

Discussion

As reported above, exposure risks related to brachytherapy with ^{125}I are limited both for operators and public. Nevertheless, alternation of operators should be considered to minimize exposure. Patient-related measurements should be carried out to verify the dose rate around the patient and to evaluate the need for shielding. An operative protocol relative to clinical, dosimetric and radiation protection issues should be carefully studied. Special efforts should be made in instructing involved personnel (physicians, technicians, nurses). The dialogue with patient and family providing all the necessary details and written documentation has proved to be effective.

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