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Schweizerische Gesellschaft für Strahlenbiologie und Medizinische Physik
Société Suisse de Radiobiologie et de Physique Médicale
Società Svizzera di Radiobiologia e di Fisica Medica

Swiss Society of Radiobiology and Medical Physics
Member of the European Federation of Organisations for Medical Physics (EFOMP) and the International Organization for Medical Physics (IOMP)

Physical aspects of intravascular brachytherapy of the coronary arteries

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Recommendations No. 14

ISBN 3 908 125 37-5 **February 2004**

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1. Introduction

Intravascular brachytherapy (IVBT) of the coronary arteries with sealed β-sources* is a relatively simple, straightforward procedure, but nonetheless poses a considerable potential for harm to patients and staff if improperly handled.

This recommendation deals with the physical and technical aspects of IVBT. It should provide the medical physicist in charge of the IVBT programme with guidance on the technical and dosimetrical quality control of the source and delivery system and on radiation protection issues. Although this document does not provide recommendations on setting up a QA system for the procedural issues of the actual IVBT procedure, it is recommended that such a system be in place before starting an IVBT programme.

IVBT is an interdisciplinary subspecialty of radiation oncology, cardiology and medical physics. As the cardiologist is a medical professional normally not familiar with therapeutical radiation issues, it is important to unambiguously define the areas of responsibility of the cardiologist, radiation oncologist and medical physicist involved in the procedure. These responsibilities should be available in written form and signed by each specialist. It is recommended that a detailed chronological checklist of the IVBT procedure is set up, defining responsibilities during each step of the procedure. In addition institutional guidelines for recording and reporting treatment parameters and dose delivered should be defined. (Comment: all items in the QA document should be followed hopefully, and known by the relevant persons)

This recommendation is based on the reports of the AAPM Task Group Nr 60 [1], the DGMP-report 16 [2] and the ESTRO recommendation [3].

* This document only adresses the dosimetry of radioactive β-sources for intracoronary brachytherapy. The dosimetry of γ-sources used for peripheral vessels will be dealt with by the SSRMP-Working Group 'Quality control in brachytherapy'.

2. Source dosimetry

This document distinguishes between the requisitions to the manufacturer and the quality assurance procedure of the user. In the following paragraphs, dose and dose rate may be used equivalently, according to the context.

2.1. Manufacturer's specifications

The manufacturer must provide a complete reference data set for his specific source design, which is assumed to be valid for all sources and upon which the treatment plans (actually the treatment times) are based.

Source strength

For each delivered source the manufacturer has to provide a certificate of the source strength $\dot{D}_{ref}$. The contained activity of the source also has to be stated. More generally, of the three values $\dot{D}_{ref}$, activity and the ratio of both, at least two have to be specified.

Dose distribution

The dose distribution around the source has to be specified by the radial depth dose function, the dose uniformity[1] and anisotropy at 2 mm distance from the source axis within water equivalent material.

The radial depth dose function is specified as the dose along a line perpendicular to the source axis and normalized to its value at a distance of 2 mm from the source axis. The dose uniformity should be specified by giving the dose distribution along a line parallel to the source axis and the anisotropy by the dose distribution along a circle around the source. Within the central area (2/3 of the length of the source), maximal and minimal dose values at a radial distance of 2 mm from the source axis should not deviate by more than 10 % from the dose value at P_{ref}.

[1] For ribbon seeds 'uniformity' is to be replaced by the characteristic undulation. For devices with source stepping, the uniformity should be measured for a single source and stepping mode. This holds true for the whole document.

2.2. User's measurements

The user has to perform consistency checks, which assure the correctness of the manufacturer's reference data set for the specific source used for treatment.

Source strength

The source strength of radioactive sources used for treatment should be verified by measuring $\dot{D}_{ref}$, or by measuring the contained activity as discussed in section 2.3.

Dose distribution

The user should verify by consistency checks that the radial depth dose function, dose uniformity and anisotropy are in agreement with the specifications of the manufacturer. Radial depth dose function is checked for at least 4 points within 2 and 12 mm distance from the source axis. Uniformity and anisotropy are checked by measuring at least three profiles along equally spaced lines parallel to the source axis in 2 mm distance from the source within a water equivalent phantom.

Frequency of measurements

These consistency checks should be performed for each newly delivered source and once a year for sources with a long half-life.

Actions to be taken

If $\dot{D}_{ref}$ deviates by more than 5 % from the stated value, the corresponding parameter in the system should be adjusted. If the depth dose rate deviates by more than 10 % for distances to the source less or equal than 5 mm and 20 % for distances to the source greater than 5 mm, the source should be rejected. If the anisotropy or the uniformity is worse than 10 %, then the source should be rejected.

2.3. Requirements for the dosimetry system

The calibration of the dosemeter should be traceable to national standards.

The high dose gradient demands high spatial resolution and precise positioning. It also demands good linearity of absorbed dose response, no saturation effect at high dose rates and sufficient sensitivity to low doses and dose rates. In addition the response has to be independent of the energy spectrum and of the angle of incidence.

Dosimetry systems based on plastic scintillators that fulfill all the above requirements are commercially available.

Alternatives

If the user can assure that the specific source which will be used for treatments yields the same dose distribution as the specified reference source, the measurement of contained activity of the source may replace absolute dosimetry. The contained activity is best measured with a well-chamber which has to be calibrated by an approved laboratory. The measured activity has to be within 5 % of that stated by the treatment system or the source certificate provided by the manufacturer.

The radiation quality, which determines the radial depth dose function, may be assessed relatively easily by a ratio of two readings on a dosemeter one with and one without an absorber between the source and the dosemeter. The reference value for this ratio may be obtained using a calibrated source[2].

The measurement of the dose uniformity and anisotropy is not as demanding to a dosimetry system as is the measurement of the radial depth dose function and can be done by film dosimetry. The film should be positioned parallel to the source axis and the conversion of optical density to dose should be taken into account.

3. Radiation protection

When using beta sources, bremsstrahlung exposure outside the treatment room is negligible and the existing shielding for X-ray angiography is sufficient. Inside the treatment room, there is essentially no exposure due to bremsstrahlung if the source is either in the patient or in the source holder. A certain dose due to beta particles and/or bremsstrahlung is detectable only when the source(s) is (are) travelling through the extracorporal part of the delivery catheter.

[2] Calibrated in terms of source strength and radial depth dose function with instruments traceable to a national standard.

The presence of the responsible medical physicist or a person expert in radiation protection and specifically trained in this kind of treatment in the cathlab during the irradiation is mandatory.

3.1. Storage room, cathlab and storage device radiation protection

A safe storage room (controlled area) must be available for the storage of the irradiation unit while it is not in use. Precautions have to be taken in order to prevent the unauthorized start-up of the treatment device.

The shielding of the device and emergency container must be such that the surface dose rate is less than 100 μSv/h.

3.2. Staff radiation protection

The use of additional ring dosimeters is recommended for the person responsible for delivering the treatment and for the expert in radiation protection present during the irradiation.

Exposure due to β-particles is limited to the time when the source is travelling through the extracorporal part of the delivery catheter. The lead aprons normally used for shielding in the cathlab are sufficient to keep the dose delivered to the staff as low as required.

Only staff necessary for the treatment should stay in the cathlab during the irradiation.

3.3. Pre and post-treatment survey

A radiation survey of the patient and the treatment room before and after the treatment is recommended in order to avoid unnoticed loss of the source or part of it and to avoid any contamination of the treatment room and the treatment staff. These measurements should be documented.

All components used for the treatment delivery must be checked for contamination after each treatment. This measurement should be documented.

3.4. Treatment survey

The control of the irradiation time should be performed by two independent timers.

The source length should be clearly indicated by radioopaque markers and visible in the fluoroscopic images.

A dummy source or a similar tool according to the manufacturer's recommendation should be used before each treatment to avoid any faulty catheter blocking of the radioactive source. The catheter should be verified to ensure that it is not leaking.

The ambient dose rate should be monitored during the whole treatment and should be documented.

3.5. Emergency

A document describing the emergency procedure including the manufacturer's recommendations should be available and known by the staff involved in the treatment. This document should be written in the common language spoken in the hospital.

An emergency container and adequate tools should be available during the whole treatment process in case of emergency.

4. Quality assurance programme

4.1. Acceptance testing of source and delivery device

A dosimetric verification should be performed if a new source and / or a new delivery device is supplied. This includes the source strength, the dose distribution and an adjustment of the corresponding treatment parameter (treatment time). For detailed description see the dosimetric part of this recommendation.

In addition a set of mechanical and functional tests should be performed. These tests should include a check of the console functions, the switches and the batteries, the timer function, the safety interlocks and the source positioning and stepping. Furthermore all radiation protection checks, which are specified by the manufacturer, should be performed. It is also recommended to check that the date, time and activity in the console memory are correct.

4.2. Pre-treatment checks

At the beginning of each working day the treatment delivery device should again be checked for its mechanical and functional performance as described in paragraph 4.1.

Before each treatment the applicator should be checked. This includes a check of the mechanical integrity of the applicator, a leakage check and a verification of the patency of the catheter pathway.

5. References

[1] Nath R., Amols H., Coffey C., Duggan D., Jani S., Li Z., Schell M., Soares C., Whiting J., Cole P.E., Crocker I., Schwartz R. Intravascular brachytherapy physics: Report of the AAPM Radiation Therapy Committee Task Group No. 60. Med. Phys. 26(2) 1999, 119-152.

[2] Quast U., Kaulich T.W., Flühs D. DGMP-Bericht Nr 16: Leitlinie zu Medizinphysikalischen Aspekten der intravaskulären Brachytherapie, ISBN 3-925218-70-X.

[3] Pötter R., Van Limbergen E., Dries W., Popowski Y., Coen V., Fellner C., Georg D., Kirisits C., Levendag P., Marijnissen H., Marsiglia H., Mazeron J.-J., Pokrajac B., Scalliet P., Tamburini V. Recommendations of the EVA GEC ESTRO Working Group: Prescribing, recording, and reporting in endovascular brachytherapy. Quality assurance, equipment, personnel and education, Radiotherapy and Oncology 59 2001, 339-360.

Appendix 1: Definitions

The definitions of the different terms used in this recommendation are given in this section. Figure 1 summarises these definitions graphically.

• Radial depth dose function: dose rate along a line perpendicular to the source axis normalized to its value at a distance of 2 mm from the source axis.

• Uniformity: dose rate variation – compared to the mean value – parallel to the source wire.

• Anisotropy: dose rate variation – compared to the mean value – along a circle around the source axis.

• Source strength: absorbed dose rate to water at a reference point, P_{ref}, located at a distance of 2 mm from the source centre.

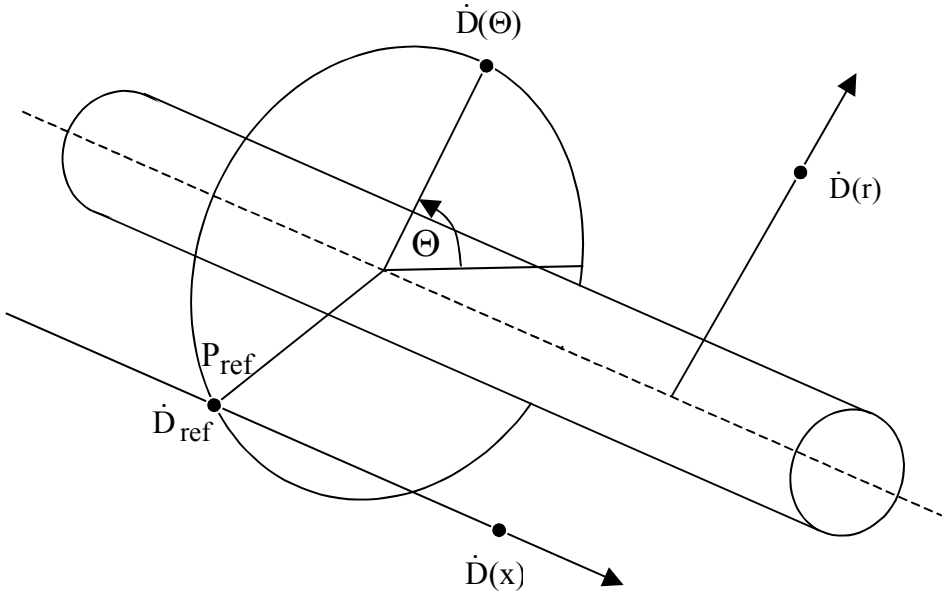

Figure 1. Schematic representation of the definitions. $\dot{D}_{ref}$ is the reference dose rate at position P_{ref} = 2mm. The variation of $\dot{D}(r)$ describes the radial depth dose function, the variation of $\dot{D}(x)$ the uniformity and the variation of $\dot{D}(\Theta)$ the anisotropy of the source.

Appendix 2: Members of the working group

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