Reports of Practical
Oncology and Radiotherapy

Dosimetry of beta sources for cardiovascular brachytherapy

Wojciech Bulski[1], Stanisław Pszona[2], Maria Kawczyńska[1]

[1]Centre of Oncology, Roentgena 5 St., 02-781 Warszawa, [2]Institute of Nuclear Studies, 05-400 Otwock-Świerk

Rep Pract Oncol Radiother **2004;9:33-6, original paper**

Received January 28th, 2004; received in a revised form April 14th, 2004; accepted April 15th, 2004

Summary

Introduction: Over a period of the last ten years the application of ionizing radiation in the prevention of restenosis in cardiovascular diseases has become a treatment of choice. The aim of this study was the verification of procedures used for the determination of the activity and uniformity of a P-32 wire source used in brachytherapy of cardiovascular disease.
Materials and methods: Measurements of activity and uniformity were carried out for beta P-32 radioactive sources used in the Galileo afterloading system from Guidant. Measurements of activity were carried out with an ionization well chamber. Source homogeneity was measured with radiochromic films.
Results and discussion: The activity of the source determined on the basis of measurements with a well chamber agreed within 1.5% with the activity values provided by the manufacturer for each source. The results show that the activity distribution along the source length is homogeneous within ±5%. The dose rate fall-off as a function of the distance from the source axis measured with a radiochromic film is in good agreement with Monte Carlo calculations.
Conclusions: Measurements of the activity of P-32 sources with a dedicated well chamber confirm with high accuracy the results of activity measurements provided by the manufacturer. The methods of measurement of source activity and uniformity presented in this paper assure proper quality of treatment planning in cardiovascular brachytherapy.
Key words: brachytherapy, cardiovascular disease, restenosis, dosimetry.

Dozymetria źródeł beta stosowanych w brachyterapii wewnątrznaczyniowej

Streszczenie

Wstęp: W okresie ostatnich dziesięciu lat zastosowanie promieniowania jonizującego w zapobieganiu restenozie było powszechnie stosowane. Celem niniejszego doniesienia była weryfikacja procedur używanych w wyznaczaniu aktywności i jednorodności jej rozkładu dla liniowych źródeł P-32 stosowanych w brachyterapii choroby wieńcowej.
Materiał i metody: Pomiary aktywności i jednorodności jej rozkładu przeprowadzono dla źródeł promieniowania beta stosowanych w aparacie Galileo firmy Guidant. Pomiary aktywności prowadzone były przy pomocy studzienkowej komory jonizacyjnej.
Wyniki i dyskusja: Dla wszystkich badanych źródeł aktywność wyznaczana za pomocą studzienkowej komory jonizacyjnej zgadzała się z dokładnością 1.5% z wielkością aktywności podawaną przez producenta. Wyniki pomiarów świadczą, że rozkład aktywności wzdłuż źródła jest jednorodny w zakresie ±5%. Spadek mocy dawki w funkcji odległości od osi źródła wyznaczony za pomocą filmów radiochromowych był zgodny z obliczeniami metodą Monte Carlo.
Wnioski: Pomiary aktywności źródeł P-32 za pomocą specjalnie dostosowanej komory jonizacyjnej potwierdziły z dużą dokładnością wartości aktywności podane na świadectwie producenta. Metody pomiarów aktywności i jednorodności źródeł przedstawione w niniejszym opracowaniu pozwalają na zapewnienie wymaganej dokładności określania wielkości dawki i zapewnienie odpowiedniej jakości planowania leczenia w brachyterapii śródnaczyniowej.
Słowa kluczowe: brachyterapia, choroba wieńcowa, restenoza, dozymetria.

Proceedings of the Conference „Current Archievements in Oncology" Poznań, 6-8 November 2003
Praca prezentowana na konferencji „Współczesne Osiągnięcia w Onkologii" Poznań, 6-8 listopada 2003

Introduction

Over a period of the last ten years the application of ionizing radiation in the prevention of restenosis in cardiovascular diseases has become a field of intensive investigation. It is an example of the use of radiotherapy for the treatment of non-oncological diseases.

One of the most effective methods of treatment of the arteriosclerotic disease is Percutaneus Transluminal Coronary Angioplasty (PTCA). However, in about 50% of cases, the process of vascular occlusion, the restenosis occurring in most cases during a period of 6 months after the primary treatment, makes the repeated PTCA necessary [1].

Restenosis is a complex process, in which the proliferation of neointimal and smooth muscle cells leads to vessel occlusion [2,3]. The use of stainless steel stents delays restenosis, but does not stop cell proliferation. The idea of using ionizing radiation to prevent restenosis has proved to be extremely promising. In many animal studies, and in the first prospective controlled clinical trials, it has been shown that radiation doses of the order of 10-20 Gy may reduce the restenosis ratio from 50% to about 10% [4,5,6,7,8].

A variety of radiation sources have been used in endovascular brachytherapy so far. The isotopes most often used are: beta emitters- P-32, Y-90, Sr-90 and a gamma emitter Ir-192 [9,10]. Ir-192 is most often used in brachytherapy of peripheral vessels. For peripheral vessels conventional HDR afterloaders are generally employed. For cardiovascular brachytherapy various irradiation techniques have been used: radioactive stents, balloons filled with radioactive liquid, radioactive wires and seeds. Currently, specially designed dedicated afterloading devices are available [11].

Dosimetry of small beta sources and treatment planning create specific technical and physical problems. Proper treatment planning requires the determination of the vessel's inner diameter. This is done by means of intravascular ultrasound examination (IVUS). Calculation of the dose delivered to the target volume requires determination of source activity and dose distribution around radioactive source.

The aim of this study was to verify procedures used in the determination of the activity and uniformity of a P-32 wire source used in brachytherapy in cardiovascular disease.

Materials and methods

Measurements of activity and uniformity were carried out for beta P-32 radioactive sources used in the Galileo afterloading system from Guidant. The sources have the form of thin wires 20 or 27 mm in length. The real source is embedded inside the tip of the leading wire of the afterloader. The outer diameter of this wire is 0.46 mm. The isotope phosphorus 32 is a pure beta emitter. The maximum energy of the emitted electrons is 1.71 MeV. The half life of the isotope is 14.3 days and, therefore, the source may be used clinically for about 4 weeks. The activity of the source, when delivered by the manufacturer, is about 150-160 mCi. The lowest acceptable activity level for treatment is about 20 mCi, but then application times become very long. In many cases, an extended application time may lead to acute pain to the patient caused by a decreased blood flow within the vessel, seriously reduced by a centering balloon, which is supposed to stabilize the position of the source in relation to the vessel wall.

Measurements of activity were carried out with an ionization well chamber Standard Imaging HDR 1000+ Well Ionization Chamber S/N A002523, coupled with Victoreen 530 electrometer. The voltage applied to the chamber was 300 V. The chamber had a valid calibration certificate from the US National Institute of Standards and Technology (NIST).

The well chamber makes it possible to perform measurements in 4 geometry (term commonly used in the literature describing detectors which record quasi-total amount of radiation emitted by a source), with a very high degree of reproducibility. The source is introduced to the well chamber through a plastic catheter of the same diameter as the catheter used for real clinical applications, which has an adapter to link it with the chamber. The measurements are performed as follows: the source is introduced to the distal position in the chamber and then is retracted in 2 mm steps, which gives 25 reading positions. In this way, the reference point of the chamber (the point of highest sensitivity, the so called "sweet spot") is determined. In *Figure 1*, the chamber sensitivity is plotted versus source position.

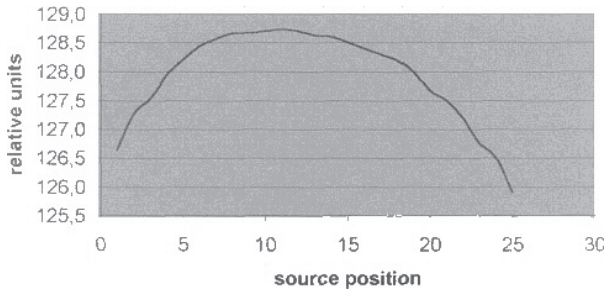

Figure 1. Well chamber sensitivity as a function of source position.

Measurements of source homogeneity were performed using radiochromic films type GAF MD55 from Nuclear Associates [12]. The films were read using an ArtixScan scanner linked to a computer system with dedicated software for a thorough analysis of the optical density of the irradiated film. These measurements also allow for the determination of the dose rate of the source as a function of the distance from the source axis. These results were

compared with Monte-Carlo calculations using the MCNP code [13].

Results and discussion

Since the beginning of 2001, the activity of about 20 sources has been measured. For each source, three series of measurements were performed. The differences between the three series were below 1 % for each source. The activity of the source determined on the basis of the measurements with the well chamber agreed within 1.5% with the activity values provided by the manufacturer for each source. Given such a short half life, a correction factor has to be calculated in terms of hours rather than days. The manufacturer provides the data on the uncertainty of the measurements with the detectors, which have the calibration coefficients traceable to a Primary Standard Dosimetry Laboratory (NIST), as 5.4% (95% confidence level). This accuracy applies only to the measurement of the contained activity of the source. Measurements of the dose rate in the vicinity of the source are very difficult and much less accurate (16 %) [11]. Primary standards for such measurements are being prepared and tested at the NIST.

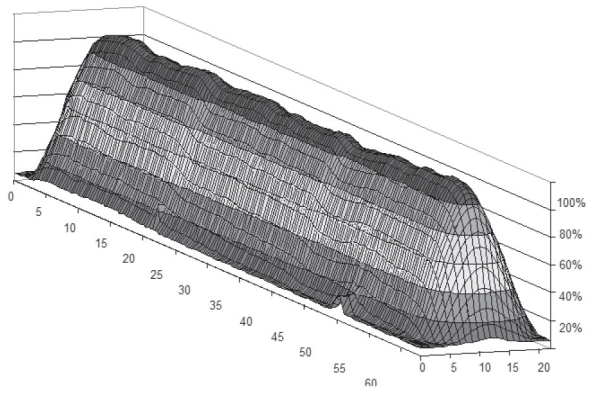

Figure 2. Optical density distribution on a radiochromic film irradiated with a P-32 wire source, 20 mm long, positioned in three 20 mm steps.

Dose rate distribution along beta sources can be measured with radiochromic films. The measurements of the uniformity of the activity distribution along the P-32 wires can be measured with specially designed ring shaped ionization chambers. Such measurements are much simpler than those used in the film technique.

The results of homogeneity measurements with radiochromic films indicate that the distribution of activity along the source length is not ideally uniform.

The Guidant P-32 source currently used is 20 mm long and is used for irradiations in two or three steps, covering the length of 40 or 60 mm, respectively. In *Figure 2*, the results of the measurements for one of the sources, which is 20 mm long, and for 3 source dwell positions are presented.

The results show that the activity distribution along the source length is homogeneous within 5%. The inhomogeneity at the junction of the source dwell positions may be even higher. This fact has to be taken into account in the analysis of dose distributions for real clinical applications.

The dose rate fall-off as a function of the distance from the source axis, measured with a radiochromic film is presented in *Figure 3*. These results are in good agreement with the Monte Carlo calculations presented in the same figure [13].

The analysis of dose distributions and the measurement methodology is under further investigation. The following factors influencing the absorbed dose distribution in cardiac vessels are being examined: the shape of the vessel wall as determined by IVUS, the screening effect of the PTCA guide wire, the presence of calcified structures within the vessel, etc. The results of these investigations will be published separately.

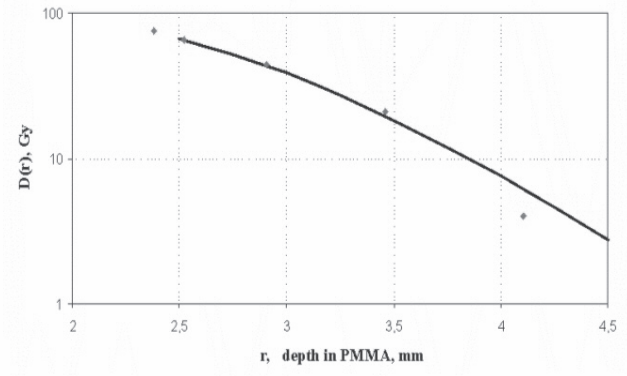

Figure 3. The depth dose curve for a P-32 wire source. Points- measured dose, solid line- the Monte-Carlo calculations.

Conclusions

Measurements of the activity of P-32 sources with a dedicated well chamber confirm with high accuracy the results of activity measurements provided by the manufacturer.

Homogeneity measurements carried out with radiochromic films indicate certain inhomogeneities for particular sources. They also allow for the establishment of a suitable distance between the consecutive source dwell positions, so that the vessel wall is irradiated in the most uniform way possible.

The methods of measurements of source activity and uniformity verification presented in this paper assure

proper quality of treatment planning in cardiovascular brachytherapy.

References

1. Pocock SJ, Henderson RA, Rickards AF, Hampton JR, King SB 3rd, Hamm CW, et al. Meta analysis of randomised trials comparing coronary angioplasty with bypass surgery. Lancet 1995;246:1184-9.
2. Sheppard R, Eisenberg MJ. Intracoronary radiotherapy for restenosis. N Engl J Med. 2001;344:295-7.
3. Bittl JA. Advances in coronary angioplasty. N Engl J Med. 1996;335:1290-302.
4. Dawson JT. Theoretical considerations regarding low dose radiation therapy for prevention of restenosis after angioplasty. Texas Heart J. 1991;18: 4.
5. Syed AMN, Gamie SH, Puthawala AA, Sharma A. Intracoronary irradiation for prevention of restenosis. J Brachyther Int. 2000;16:73-93.
6. Verin V, Popowski Y, De Bruyne B, Baumgart D, Sauerwein W, Lins M, et al. Endoluminal beta-radiation therapy for the prevention of coronary restenosis after balloon angioplasty. N Engl J Med. 2001;344:243-9.
7. Leon MB, Teirstein PS, Moses JW, Tripuraneni P, Lansky AJ, Jani S, et al. Localized intracoronary gamma – radiation therapy to inhibit the recurrence of restenosis after stenting. N Engl J Med. 2001;344:250-6.
8. Teirstein PS, Massullo V, Jani S, Popma J, Mintz GS, Russo RJ, et al. A subgroup analysis of the scripps coronary radiation to inhibit proliferation poststenting trial. Int J Radiat Oncol Biol Phys. 1998;42:1097-104.
9. Amols HI, Weinberger J. Intravascular brachyterapy physics: Review of radiation sources and techniques. Vascular Brachytherapy. Editor Nucleotron BV Holland 1996;104.
10. Crocker I. Perspectives on choice of radioisotopes, delivery and dosimetry of vascular irradiation. Vascular Brachytherapy. Editor Nucleotron BV Holland 1996;94.
11. Mourtada A, Soares ChG, Seltzer M, Lott SH. Dosimetry characterization of 32P catheter- based vascular brachytherapy source wire. Med Phys. 2000;27:1770-6.
12. Soares CG, Vynckier S, Järvinen H, Cross WG, Sipilä P, Flühs D, et al. Dosimetry of beta-ray ophthalmic applicators: Comparison of different measurement methods. Med Phys. 2001;28:1373-84.
13. Wincel K, Zaręba B. Monte Carlo calculations of dose distribution for 32P brachytherapy wire source. Pol J Med Phys Engl. 2002;8:63-9.