Source Strength Measurement of Brachytherapy Sources

I Introduction

Low dose rate (LDR) brachytherapy seeds for permanent seed implantation are tiny pellets for direct implantation into a cancerous tumor. Nowadays seeds are typically about the size of a rice grain, consisting of a titanium capsule containing radioactive isotopes I-125 or Pd-103. Tumors of eye, head, neck, lung, pancreas and early stage prostate are commonly treated. Prostate cancer is the most common form of cancer in men. Good results in treating prostate cancer in conjunction with the advantages of a minimum outpatient procedure and high quality of live helps to spread this technique.

II Quality Assurance

The AAPM Task group 56 presents recommendations as a code of practice [2].

Extracts of these recommendations concerning quality assurance in brachytherapy with seeds are listed here:
- It should no longer be a practice to rely on source strengths quoted by the manufacturer.
- Ideally, every radioactive source that is to be implanted in a patient should be calibrated. In practice however this is not possible.
- For groupings with a large number of loose seeds, a random sample of at least 10% of the seed group should be calibrated.
- For sources purchased in a sterile configuration a single (nonsterile) seed for each designated-strength grouping should be purchased and calibrated.

Measuring quantities:
Although different institutions [2], [3] strongly advise that the obsolete quantity apparent activity $A_{app}$ should no longer be used for source strength specification of seeds, it is still widely used, particular by vendors.

<table>
<thead>
<tr>
<th>Nuclide characteristics</th>
<th>Pd-103</th>
<th>I-125</th>
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</thead>
<tbody>
<tr>
<td>Half life [1]</td>
<td>16.97 days</td>
<td>59.4 days</td>
</tr>
<tr>
<td>Emitted gamma rays [1]</td>
<td>20.1 keV</td>
<td>27.4 keV</td>
</tr>
<tr>
<td>Air Kerma rate at 1m (typ.)</td>
<td>(0.1 ... 8) µGy/h</td>
<td></td>
</tr>
<tr>
<td>Apparent activity (typ.)</td>
<td>(3.7 ... 300) MBq</td>
<td>((0.1 ... 8) mCi)</td>
</tr>
</tbody>
</table>

The recommended source strength description today is air kerma strength $S_0$ (air kerma rate at a certain distance in air). The unit is µGy h$^{-1}$ m$^{-2}$.

Apparent activity and air kerma rate are related by a seed specific air kerma rate constant.

Figure 2: SourceCheck source strength device

Calibration factors:
For each seed design a calibration factor has to be determined, even if the same radionuclide is used. [4]

The reason for this is the high absorption of low energy gamma rays in the capsulation of the seed.

Currenty only NIST [5] can provide reference air kerma rate calibrations for seeds.

TG-56 recommends that every institution practicing brachytherapy should have a system for measuring source strength with secondary traceability for all source types used in its practice.

Secondary traceability is established, when the source is calibrated by comparison with the same radionuclide and design that has a directly traceable calibration, or by a transfer instrument that bears a directly traceable calibration. [2]

The vendors of the seeds offer reference seeds with a stated value measured by an ADCL [6]. With these seeds a calibration factor can easily be established by comparison measurement. The long term stability of the dosimetry system should be verified with a long life source.

For brachytherapy sources that do not have a national standard yet users should develop a constancy check calibrated against the vendor’s standard and use this constancy check to verify the source strength. [2]

Sterility
Seeds can be ordered as loose seeds or as seeds in a suture, e.g. Nycomed Amersham RAPID Strand™ seed strands.

A RAPID Strand™ consists of 10 single I-125 seeds spaced at fixed distances of 1 cm center to center within a braided absorbable suture. They are delivered sterile. Loose seeds are not sterile and need to be sterilized prior to use. [1]
III. PTW Products for QA

CURIENTMOR 3 isotope calibrator

CURIENTMOR 3 (see figure 3) is a new isotope calibrator for nuclear medicine and LDR seed measurement.

Figure 3: CURIENTMOR 3 isotope calibrator

The well type chamber is filled with 10 bar argon gas. The reading can be displayed in MBq (or Ci), or in pA to calculate air kerma strength.

The insert to place the seeds in the chamber is a user friendly acrylic funnel (T23365/U901-1).

SourceCheck source strength device

SourceCheck (see figure 2) is an ionization chamber specially developed for source strength measurement in brachytherapy. The chamber is 220 mm long and provides a sensitive area (sweet spot) of approx. 120 mm. An acrylic guide tube is located in the center of the chamber to accommodate the radioactive source to be measured. Sources placed inside the chamber are measured in a full 4π geometry. The specially designed chamber wall allows to place a source outside the chamber, too. The long term stability of the chamber can be checked using a Sr-80 radioactive check device which is placed in an acrylic adapter on the outside surface of the chamber.

Due to the unique design of the chamber a low leakage current and a very good response for I-125 and Pd-103 is provided.

a.) Single seeds:
Single seeds can be placed inside the chamber. The seeds must be sterilized after the measurement.

b.) RAPID Strands:
The entire strand can be measured without being removed from it’s sterile delivered spacing jig.

The jig is to be placed in a source holder which keeps the strand close to the outer surface of the flat chamber. The source holder can be sterilized.

An entire strand, or single seeds of the strand can either be placed inside the chamber if no sterility is required.

c.) Loaded Needles:
Loaded needles can be placed inside the SourceCheck chamber for quality control. They have to be sterilized after the measurement.

IV. Other Applications for SourceCheck

SourceCheck is well suitable for further measuring tasks in brachytherapy:

a.) Measuring IVB Sources with SourceCheck

Coronary artery disease is one of the leading causes of mortality in the western world. Modern medicine established well proven techniques to fight against this disease. Besides bypass surgery coronary angioplasty is a common way of treatment. The major limitation of angioplasty is restenosis, which occurs in many cases after balloon angioplasty and after stent implantation.

Many studies indicate that using ionizing radiation reduces the occurrence of restenosis. Several different systems for intravascular brachytherapy (IVB) have been developed. The most promising systems are afterloading systems using a sealed radioactive source.

The source strength of these sources can be measured with SourceCheck using the appropriate adapter.

The sources from GUIDANT (Galileo®) and CORDIS (Checkmate®) can be placed inside the chamber. For the NOVOSTE system (Beta-Cath®) an adapter is available to place the measuring catheter outside the chamber. Systems from other manufacturers can be adapted easily.

For further information about QA in IVB please refer to the application note D620.208.0/0 (Dosimetry in Intravascular Brachytherapy).

b.) Measuring HDR Afterloading Sources with SourceCheck

AAPM TG-56 recommends that a qualified medical physicist shall calibrate each HDR/PDR source prior to clinical use in terms of air kerma strength and use this value as the basis for treatment planning and treatment prescription [2].

The applicator probe used for the source strength measurement can be placed inside the chamber. Calibration factors for commercial available afterloaders are provided.

Further information about QA in HDR Afterloading can be found in the application note D432.208.0/0 (Dosimetry in Afterloading Brachytherapy).

V. Conclusion

Quality assurance for permanent implanted seeds requires fast, precise and easy to handle measuring equipment. PTW-Freiburg offers two different systems for this task:

CURIENTMOR 3: A complete measuring device for seed measurement.

SourceCheck: The flat ionization chamber specially designed for seed measurement.

The SourceCheck chamber is suitable for several tasks in Brachytherapy.


[3] SSDL-Newsletter No.43, July 2000, ISSN 1011-2669


[5] NIST, National Institute of Standards and Technology. USA

[6] ADCL, Accredited Dosimetry Calibration Laboratory