Dosimetry of β-emitting Radioactive Implants ◇

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Brachytherapy is a special kind of radiotherapy where radioactive sources are used to deliver a high radiation dose at a short distance locally to the target volume with rapid dose fall-off in the surrounding tissue. Within the RadBioMat-project [1] radioactive implants are developed for this purpose using the pure β-emitter ^{32}P with a mean electron energy E_{mean}= 0.7 MeV. The therapeutic range of 0.7 MeV electrons is only about 3 mm and the deposited dose of a ^{32}P point source falls off from 0 to 1 mm distance in tissue by about 80%. Dose distribution measurements have to be made, therefore, with a space resolution of 1 mm or better which is at the limit of todays β-dosimetry. Measured dose distributions are compared with computer simulations which in turn are used for dose planning in radiotherapy.

To measure dose distributions with this precision a detector setup with 4 stepper motors has been built using a scintillation detector system with 0.8 mm^3 sensitive volume (Type 60006, Optidos, PTW Freiburg). Detector and radiation source are mounted inside a small water pool ("water phantom") to simulate tissue equivalent conditions. An alignment telescope was used to measure the actual distance between detector and source as 0.1 mm change results in a dose difference of more than 10%. On the other hand dose distributions should be known better than 5% in radiation therapy.

Dose distribution measurement of a small ^{90}Sr calibration source (cylinder: 0.5 mm diameter and 0.5 mm long) is shown in Fig. 2. This source was also calculated by the GEANT4 [2] Monte-Carlo code, using the low energy extension (down to 250 eV). The measurement is systematically about 10% lower than the calculation but still within the given calibration error of the detector system of 16%. The GEANT4 simulations, however, are found to be in perfect agreement with calculations using the well known EGSnrc code.

As no direct comparison can be made between measurement (output is dose in Gy) and simulation (input is activity in Bq), our liquid scintillation system (TriCarb, Perkin Elmer) was used to measure the activity of the radioactive samples and link dose and activity. After the dose distribution measurements the implants were dissolved into liquids and their total activity measured. To improve the accuracy a cross check was made with a calibrated ^{32}P solution. The systematic deviation of the scintillation detector was confirmed and could be partly explained in simulations with the special calibration geometry of the detector.

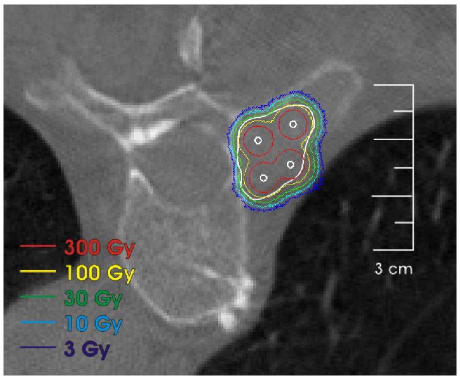

Fig. 1: Dose distribution of four brachytherapy sources near the spinal. Calculated according to the given CT–DICOM data. The target volume is marked by the white line.

In addition to calculations of simple geometries we implemented a way to use computer tomography (CT) pictures to generate the tissue geometry. The DICOM files from the CT are used to calculate the material and the density from the Hounsfield units [3]. We are even able to place any other geometry / source into the volume generated out of the CT images. With this method we can calculate the dose distribution of any source in any given human body part. An example is given in Fig. 1.

References

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[2] S. Agostinelli *et al.*, NIM A **506** (2003) 250-303
[3] W. Schneider *et al.*, Phys. Med. Biol. **45** (2000) 459-478

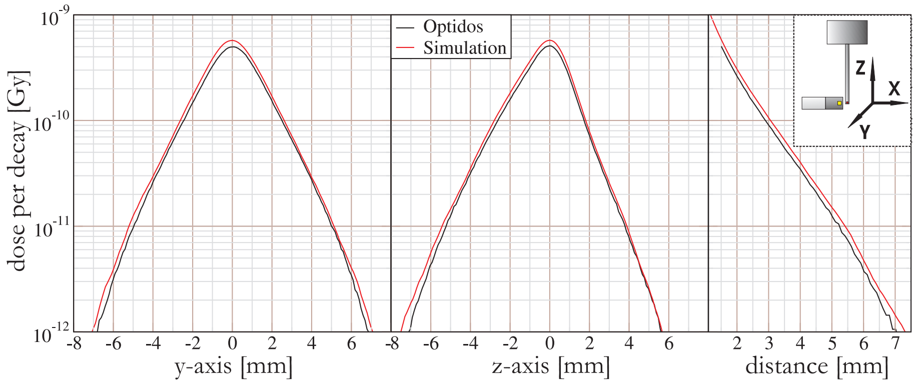

Fig. 2: Comparison between Geant4-calculations and OPTIDOS-measurements on a ^{90}Sr calibration point source. The z-plot asymmetry is caused by the self-absorption of the needle itself.

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