Commissioning of a soft X-ray source for intraoperative breast irradiation

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Introduction

The Intrabeam System (Carl Zeiss Surgical GmbH) offers a method for treating breast cancer [3]. The radiation dose is administrated to the tumor bed in the operating room, following lumpectomy. A radial symmetrical dose distribution is predicted from the company. This system utilizes a miniature X-ray tube, a support stand and a range of applicator options. Patient dose is calculated with a treatment planning system (TPS) containing customer specific basic data of tube and applicators entered by the company. In this work we present the commissioning of this device based on the BAG (Bundesamt für Gesundheit, Bern) and SGSMP recommendations.

Material and Methods

In the X-ray tube (type XRS) a electron beam is focussed on a hemispherical gold target, generating soft photons [4,5] with energies up to 50 kV. A spherical applicator made of water equivalent material (applicator diameter from 1.5 cm to 5 cm) surrounds the target. Relevant criteria to achieve security/functionality and parameters to get the right dose at the right place (geometry/dosimetry) are checked [1,2]. The absolute dosimetry was performed with a PTW 23342 ionisation chamber embedded in a PMMA-plate placed under 7 cm water. Absolute dose from the applicators and different applicator-chamber-distances were measured and compared with beam data generated by the company. For relative dosimetry the PTW 23342 chamber was also used. The TPS was checked by manual calculation based on the beam data.

Results

The tube fixing stand is meant to follow the thorax wall motion due to breathing with an amplitude up to about 1 cm. No leakage of the dose monitor and no radiation leakage during the system immanent QA procedure were detected. The deviation of the linearity of the dose monitor up to 60 Gy was $R^2=1-10^{-4}$. The beam switch on/off effect of was (0±1)% by 1x10 Gy vs. 10x1 Gy with the smallest applicator. The deviation of angular homogeneity perpendicular to the electron path is less than 2%. The deviation of angular homogeneity parallel to the electron path can rise up to 20%. The half value layer is (1.25±0.2) mm Al. The deviation TPS vs. manual calculation is within 1% and is generated by interpolation of the measurement of the basic data and the determination of the calibration factor N_w from N_Q. The deviation from absolute dosimetry measurements vs. basic data of the TPS is about ±5% mostly generated by the inaccuracy of the focus-chamber-distance measurement (±1 mm) depending on this distance itself and the size of the entrance window of the ion chamber.

Discussion

Main disadvantages of the system are a) no verification of the applicator size at the control unit, b) no backup dose monitor available, c) no verification of the position of the applicator in the patient during irradiation, d) no correction of the TPS according to small volumes and tissue inhomogeneities e) large radial inhomogeneity of the dose distribution. Main advantages are a) the system immanent QA procedure has to be performed before each irradiation, b) automatic correction of the beam output to the target value.

References

[1] BAG-Weisung R08-09 (Qualitätssicherung bei Röntgentherapieanlagen; 10.02.2005)
[2] SGSMP recommendation No. 9 (Dosimetrie von Röntgenstrahlen im niederen und mittleren Energiebereich; Mai 2001)
[3] Kraus-Tiefenbacher, U. et. al.: Intraoperative Radiotherapy (IORT) for Breast Cancer Using the Intrabeam System. Tumori, 91, 2005, 339-345
[4] Dinsmore, M. et al.: A new miniature x-ray source for interstitial radiosurgery: Device description. Med. Phys. 23 (1), 1996, 45-52