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## Photon Radiosurgery System – time stability of the calibration parameters

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### Summary

<b>Aim</b>	The aim of the paper is to present the time stability of the calibration parameters of a miniature 50 kV Photon Radiosurgery System used during surgical procedures to irradiate tumour beds.
<b>Materials/Methods</b>	Before tumour irradiation, calibration procedures were performed and individual treatment times were calculated. During quality control procedures, parameters such as probe straightness, isotropy of the beam and stability of the internal and external monitors were checked. Also output dose rate was measured.
<b>Results</b>	The average values of the parameters measured, and percentage deviations (1 SD) thereof, were as follows: probe straightness 0.035 mm (22.1%); isotropy of the beam 5.72% (3.5%); internal monitor reading $8.182 \text{ E}4 \text{ } 10^4$ (0.7%); external monitor reading 2.932 Hz (3.1%); output dose rate 2.731 Gy/min (1.8%).
<b>Conclusions</b>	High stability of the calibration parameters was observed. Measurement of probe deviation is a necessary condition in each radiotherapy procedure.
<b>Key words</b>	<b>low energy X-rays • radiosurgery • interstitial radiotherapy</b>

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**BACKGROUND**

The Photon Radiosurgery System – as shown in Figures 2–4 – is usually used to provide localized dosing to tumour beds at the time of clinical resection. The miniature x-ray source consists of an electron accelerator with a gold target at the end of a probe. The electrons are accelerated to the desired energy level and focused down the probe to strike the target resulting in an isotropic distribution of radiation around the tip of the probe [1–3].

Specialised spherical applicators ranging from 1.5 to 5 cm are applied. Because of the low energies (20–50 kV) emitted by the miniature X-ray source (XRS), the system can deliver high doses to relatively small areas of tissue, ensuring that adjacent normal tissue and critical organs receive minimal radiation doses [4–7]. This procedure reduces the need for post-surgical radiotherapy. The system requires quality control procedures to be undertaken and such procedures may include: probe adjustment, beam isotropy adjustment, internal and external monitor stability testing and evaluation of the output dose rate.

**AIM**

The aim of the paper is to present the stability of the calibration parameters with time.

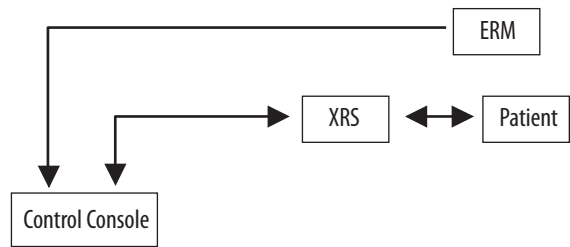
**MATERIALS AND METHODS**

The PRS-400 System produced by the Photoelectron Corporation and Carl Zeiss was used.

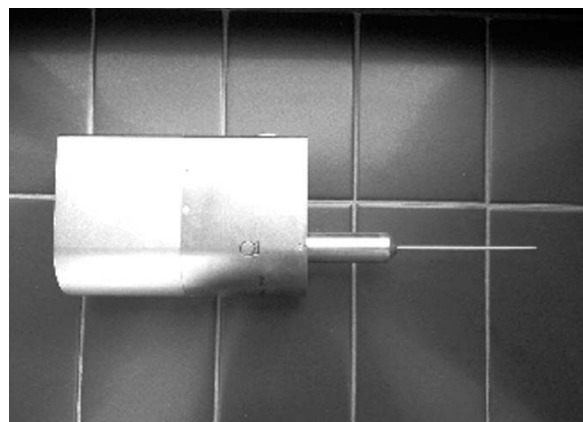
- The verification procedure consisted of 4 steps:
- verification of the probe straightness and straightening if required (Probe Adjust),
  - tuning the XRS radiation field (Isotropy Adjustment),
  - testing the Internal Radiation Monitor and External Radiation Monitor (IRM and ERM test),
  - measuring the XRS Probe radiation output dose rate (Read Ion Chamber).

**Probe Adjust Procedure**

The probe is a needle shape structure (Figure 2) with a vacuum, through which the electron beam passes and strikes the target at the end of the probe. Ideally, the probe should be straight in order to assure proper spherical dose distributions. A dedicated optical system was used to check whether the



**Figure 1.** Block diagram of the PRS400.



**Figure 2.** X-Ray Source (XRS).

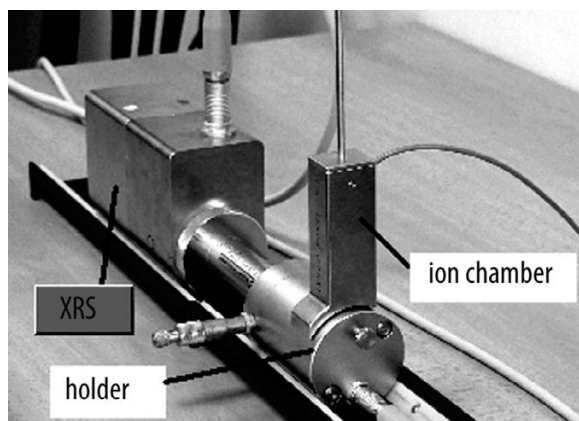


**Figure 3.** XRS combined with a balanced floor stand.

probe was straight, within the range of a 0.1 mm limit. If the straightness of the probe was found to be outside of the allowed limit it was straightened using special mechanical equipment.

**Isotropy adjustment**

Isotropy Adjustment is a semiautomatic procedure. It is used to optimize the isotropy of the emitted X-ray beam. The probe was inserted



**Figure 4.** The output dose rate in water was determined from the measurement in air using a dedicated device.

into a special device containing five photodiodes, placed symmetrically around the probe. During beam emission, the signal from the diodes was analyzed. The degree deviation, as a percentage, between the signals from each of the photodiodes was taken into consideration. The PRS system performs self-calibration in order to ensure that differences between results from diode to diode are minimal (in the range of 6%).

**IRM/ERM test**

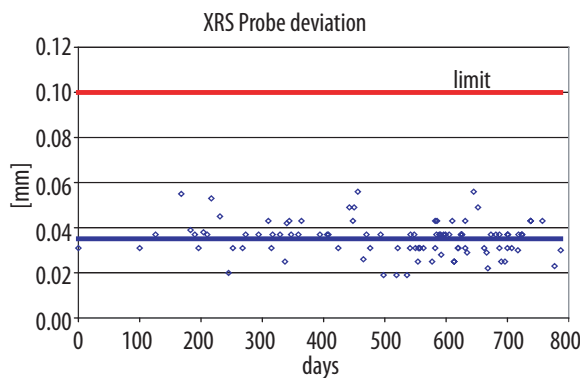
During treatment, an Internal Radiation Monitor and an External Radiation Monitor were used to assess the stability of the beam and the dose given to the patient. As a result of the IRM calibration procedure, the count rate, in Hertz and corresponding to the output dose rate, could be determined. Using the IRM count prior to treatment, the total IRM count required for planned doses could be calculated. Besides treatment time, this IRM count data must be entered into the PRS console prior to treatment. This is a necessary safety requirement.

**Output Dose Rate Measurements**

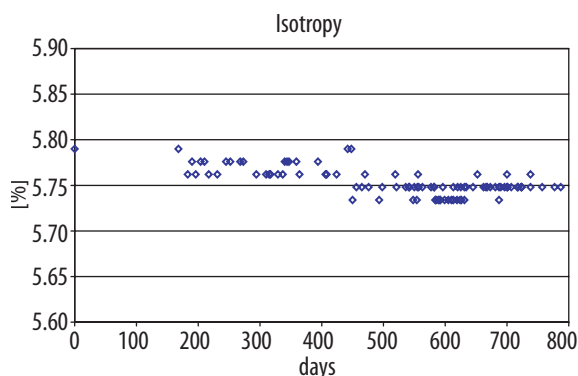
For the purpose of measuring the output dose rate, a parallel plate ion chamber (type 23342) and the UNIDOS (PTW) electrometer were used. The output dose rate in water was determined from the measurement in air using a dedicated device (Figure 4). The percentage depth dose curve for all applicators was evaluated according to the procedures and specifications of the manufacturer.

**RESULTS**

During the last 2 years over 90 calibration procedures have been performed (one before every



**Figure 5.** Deviation of the needle [mm].



**Figure 6.** Differences in beam isotropy [%].

treatment). Checking the straightness of the needle is a basic test. It influences the results of the other measured parameters (isotropy, dose rates). Deviation of the needle, measured in mm, is presented in Figure 5.

The average deviation in needle straightness, from the optimal position, was 0.035 mm (SD=22.1%), well within the tolerance limit (0.1 mm).

**Isotropy**

The differences in beam isotropy, as a percentage, between diode readings is presented in Figure 6. The average isotropy amounted to 5.754, SD=0.3%

**IRM Test**

The data for IRM count is presented in Figure 7.

There are two groups of data visible in Figure 7. The average count value for the first group was  $8.251 \cdot 10^4$  Hz (SD=0.3%) and for second group,  $8.143 \cdot 10^4$  Hz

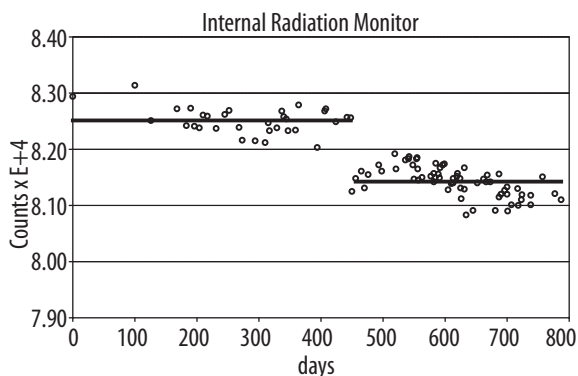


Figure 7. Data for IRM count.

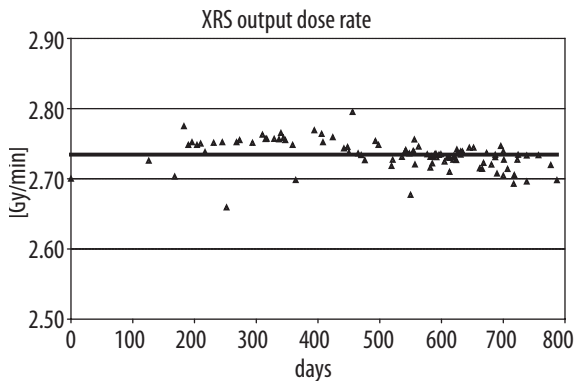


Figure 9. Measurements of output dose rate data.

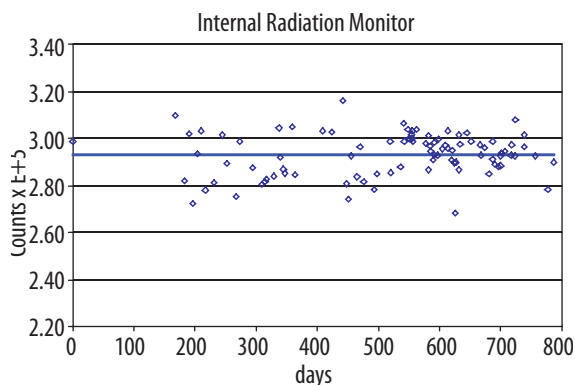


Figure 8. ERM count rate data.

(SD=0.3%). The reason for this difference was the use of a second XRS control console.

**ERM Test**

The ERM count rate data is presented in Figure 8. The average value was  $2.931 \cdot 10^5$  Hz, SD=3.1%.

**Output Dose Rate Measurements**

Measurements of output dose rate data are presented in Figure 9. The average value was 2.735 Gy/min, SD=0.8%.

All calibration parameters remained stable within the observed period of time (except for IRM count rate). The depth dose curves for some applicators used, at an energy of 50 kV, are presented in Figure 10. The dose falls off approximately by a third power of the distance.

In a few cases, the treatment session was interrupted owing to dosimetric problems, as determined

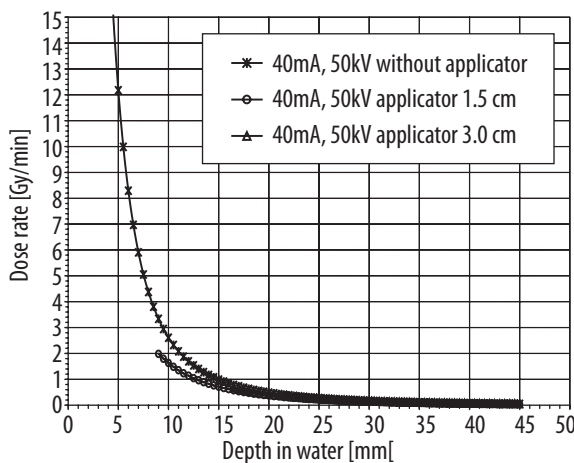


Figure 10. Depth dose curves for applicators used (at 50 kV).

by internal and external monitors. After checking the system it was found that the probe was not sufficiently straight (with the range of 0.1 mm).

**CONCLUSIONS**

High stability of the calibration parameters of the Photon Radiosurgery System were observed. The essential factor having an influence on the stability of the system during radiotherapy procedures is the straightness of the needle shaped probe. That being the case, before any radiotherapy procedure, the measurement of probe deviation is an absolute requirement.

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