Accuracy contra work load in In Vivo Dosimetry I

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INTRODUCTION I

The use of In Vivo Dosimetry has been widely spread during the last years as one important part of the quality assurance chain in radiation therapy. It is the only independent way to check the dose given to the patient during the actual treatment. The semiconductor detector is well suited as a detector for In Vivo Dosimetry if the detector shows acceptable characteristics, as will be discussed below.
It is well known that some or several characteristics can be affected when the detector has been used in high-energy radiation beams. The ***sensitivity*** is one parameter, which will be effected. The sensitivity will go down after some time of use. Another effect is ***the dose rate linearity.*** For some types of detector, the signal will not be proportional to the dose-rate, and in some cases this non-linearity will change with accumulated dose**.** This will lead to an incorrect reading if the dose rate in the measuring position will differ compared with the calibration situation. A third effect is the ***sensitivity variation with temperature*** (SVWT), which means that the signal per unit dose from the detector will change with the temperature in the detector. A fourth effect is ***the detector leakage current,*** which is correlated to the detector impedance. This parameter can be of importance if the measured dose rate is very low and an offset voltage of the input amplifier will arise. Other important effects of the detector design, which have to be considered is the ***directional*** and ***the field size dependencies*****.** All this parameters must be considered in a clinical situation, and correction factors have to be applied to the reading at the same time, as the variation with time of use (radiation damage) must be analysed.
As the number of parameters to handle will increase the work load for the physicist in the quality control of the in-vivo system, the influence of these parameters have been investigated in a 15 MV x-ray.

METHOD I

Semiconductor detectors aimed for in-vivo dosimetry from three different manufacturers were investigated in 15 MV x-rays from a medical accelerator, General Electric. Three detectors each from Sun Nuclear (Sun), QED type 15-25MV, PTW (PTW), type T60010H-4 and from Scanditronix Wellhöfer (Scx), type EDP 20^{3G}, were investigated. They were all investigated with respect to parameters that can be affected by radiation damage, i.e. the sensitivity drop, the dose rate linearity (dose per pulse), the SVWT and the detector leakage current. Also the directional and the field size dependencies were investigated. The same integrating electrometer, with a low input bias current (<0.1 pA) and a low input bias voltage (<50 µV) was used together with all detectors.
All pre-irradiations were performed in small dose steps up to 1 kGy with a dose rate of about 6 Gy/min.
The SVWT was measured by placing the detector in close contact with a phantom of 20 and 35 centigrade respectively, and covering the detector with a thermal insulating layer of Styrofoam. After thermal equilibrium was attained, the temperature and the sensitivity of the detector were assessed.
The dose rate linearity was measured at two different distances from the focus on a 5 cm thick polystyrene phantom, SSD 100 cm and SSD 220, giving a dose rate variation of about 5.

The detector leakage current was measured with a reverse voltage of 1.6 V.
A reference value for the four parameters that can be affected by the radiation history was first obtained with the detectors un-irradiated. The same measurements were then repeated after the different pre-irradiation dose levels.
The field size and directional dependencies were investigated on a 5 cm thick polystyrene phantom at an SSD of 100 cm. Results were compared with readings from an ionisation chamber.

RESULTS I

Sensitivity drop

As can be seen in table 1 the sensitivity drop was about 2 % for Sun and 4% for Scx and about 20 % for the PTW detector after 1 kGy in 15 MV x-rays.

TABLE 1

Remaining sensitivity in % after irradiation in 15 MV x-rays. Pre-irradiation with a dose rate of about 6 Gy/min.

Pre-irradiation level (Gy)	0	1000
PTW	100	80
Sun	100	98
Scx	100	96

Dose rate linearity

The dose rate linearity for the different detectors up to a pre-irradiation dose of 1 kGy showed that the Sun and the Scx detectors remained linear, but the PTW detectors showed 6% non-linearity.

Sensitivity variation with temperature (SVWT)

The SVWT is shown in table 2 and as can be seen the Sun and the Scx detectors remained unchanged after pre-irradiation. The Sun detectors showed, however, a higher value, about 0.5% compared with 0.2% for the Scx detectors. The PTW detectors showed a small value when un-irradiated, but increased after pre-irradiation.

TABLE 2

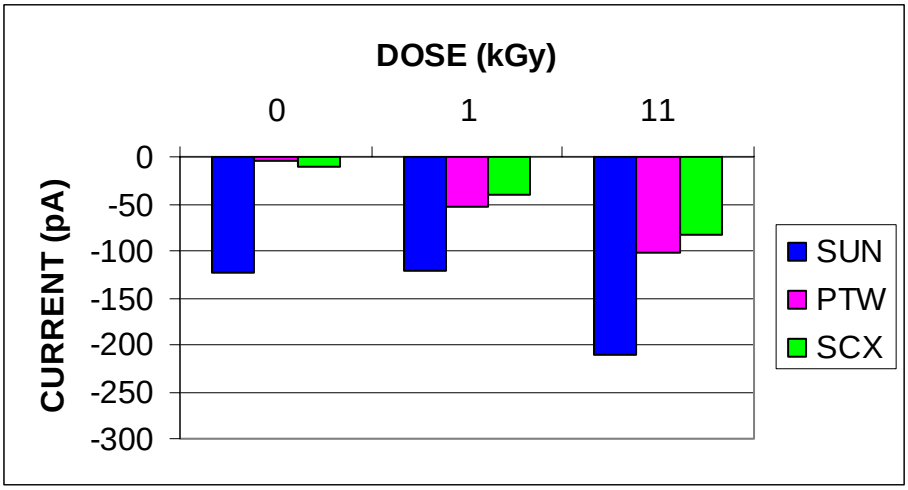
Sensitivity variation with temperature, % per centigrade, un-irradiated and after 1 kGy in 15 MV x-rays.

Dose level	0 Gy	1000 Gy
PTW	0,1	0,2
Sun	0,5	0,5
Scx	0,2	0,2

Leakage current
Also the leakage current increased for all detectors, with the lowest value for the Scx and PTW detectors as is shown in Graph 1.

GRAPH 1

Leakage current as a function of pre-irradiation dose



Directional dependence
Table 3 shows the directional dependencies. A decrease in signal for incident angles larger than 30 degrees was noticed for all detectors. The smallest variation was noticed for the PTW detectors.

TABLE 3

Relative sensitivity for different incident directions. Measured at SSD 100 cm and a field size of 10 x 10 cm, 15 MV x-rays. Normalised to 0 degrees.

Direction	0 degrees	15 degrees	30 degrees	45 degrees	- 45 degrees
PTW	1,0	1,00	0,99	0,99	0,99
Sun	1,0	1,00	0,98	0,98	0,97
Scx	1,0	1,00	0,99	0,98	0,97

Sensitivity variation with field size
The sensitivity variation with the field size was shown to be small for the Sun and the Scx detectors, but pronounced for the PTW detectors as is shown in table 4.

TABLE 4

Field size dependence. 15 MV x-rays, SSD 90 cm. Normalised to 10 x 10 cm.

Field size (cm)	5x5	10 x 10	15 x 15	20 x 20
Reference ratio	**0,935**	**1,0**	**1,042**	**1,064**
Measured ratio PTW	0,971	1,0	1,010	1,011
Deviation PTW (%)	**3,8**	**0**	**- 3,2**	**- 5,0**
Measured ratio Sun	0,943	1,0	1,035	1,057
Deviation Sun (%)	**0,9**	**0**	**- 0,8**	**- 0,7**
Measured ratio Scx	0,938	1,0	1,047	1,072
Deviation Scx	**0,3**	**0**	**0,5**	**0,8**

DISCUSSION I

Correction factors have to be applied to all detectors if a high accuracy shall be achieved. In general, the smaller correction factors, the better it is, which implies less workload and also a higher accuracy. However, correction factors which will change, as an effect of radiation damage will be **very** difficult to handle in a clinical situation. The results indicate that all detectors must be considered with respect to the sensitivity drop. The result shows that the PTW detectors must be calibrated about 4 or 3 times more frequent compared with the Sun and Scx detectors respectively. A dose rate non-linearity of 6 %, as was shown for the PTW detectors, will cause deviations in the results, especially when measuring at SSDs, which differ from the calibration situation. Also in wedged fields, generated by a “hard wedge”, large deviations will occur for the PTW detector. If calibrated at a temperature of 27 centigrade the maximum effect of the SVWT will be about 1% for the SCX detector and about 2.5% for Sun. The PTW detector showed a low value when new, but increased with time of use. The field size dependence was small for the Sun and the Scx detectors, but large for the PTW detector.

The Sun and Scx detectors showed rather similar results for most parameters except for the SVWT and the detector leakage current, where the Scx detectors showed better values. For these detectors, however, no parameters changed as a function of radiation damage, except the sensitivity. But the PTW detectors showed large variations in several parameters. Effects of radiation damage caused a continuous change in some parameters and these detectors should be difficult to use in a clinical situation.

All results show the mean values from three different detectors. The individual variations were small.