Radiation Measurements 46 (2011) 436–439

Contents lists available at ScienceDirect

Radiation Measurements

journal homepage: www.elsevier.com/locate/radmeas

Effects of radiation scatter exposure on electrometer dose assessment in orthovoltage radiotherapy

Martin J. Butson [a,b,c,*], Peter K.N. Yu [a], Tsang Cheung [a], B.M. Oborn [b,c]

[a] City University of Hong Kong, Dept. of Physics and Materials Science, Kowloon Tong, Hong Kong
[b] Illawarra Cancer Care Centre, Department of Medical Physics, Crown St, Wollongong, N.S.W 2500, Australia
[c] Illawarra Health and Medical Research Institute and the Centre for Medical Radiation Physics, University of Wollongong, Northfields Ave Gwynneville, N.S.W, Australia

ARTICLE INFO

Article history:
Received 31 May 2010
Received in revised form
4 January 2011
Accepted 17 January 2011

Keywords:
Orthovoltage
Radiation
Radiotherapy
Dosimetry
Scattered radiation
Exposure

ABSTRACT

During orthovoltage x-ray radiotherapy dosimetry, normal practice requires the use of a standard ionisation chamber and dedicated electrometer for dosimetry. In ideal conditions, the electrometer is positioned outside the treatment room to eliminate any effects from scatter radiation on dose measurement. However in some older designed rooms, there is no access portal for the chamber cable to run to an "outside" position for the electrometer. As such the electrometer is positioned within the treatment room. This work quantifies the effects on measured charge when this occurs. Results have shown that with the electrometer positioned next to a solid water dosimetry stack and using a large 15 × 15 cm field at 250 kVp x-ray beam energy, charge results can deviate by up to ±17.2% depending on the polarity applied to the chamber compared to readings when the electrometer is outside the treatment room. It is assumed to be due to scatter radiation producing electrons in the amplifying circuit of the electrometer. Results are also shown when the electrometer is shielded by a 4 mm thick lead casing whilst inside the room which removes the scattering effect, providing the best case scenario when the electrometer must remain in the treatment room. Whilst it is well known that an electrometer should not be irradiated (even to scattered radiation), often small kilovoltage or orthovoltage rooms do not have a portal access for an electrometer to go outside. As such it would be recommended for a lead shield to be placed around the electrometer during irradiation if this was to occur to minimize dosimetric inaccuracies which may occur due to scattered radiation effects.

1. Introduction

Superficial and Orthovoltage x-ray units have been used extensively in radiotherapy for a long period of time (Mondalek et al., 1988; Zarand, 1979; Podgorsak et al., 1998; Kurup and Glasgow, 1993; Butson et al., 1995). Historically, the terms superficial is used for energies in the range of 50 kVp to 150 kVp and orthovoltage for 150 kVp to 500 kVp. These machines still have a place in a radiotherapy department for the treatment of superficial cancers as well as bone metastasis. As part of their clinical use, radiation dosimetry needs to be performed on a regular basis (Cheung et al., 2009; Butson et al., 2008 Mar; Butson et al., 2008 Sep 7; Butson et al., 2008 Sep; Butson et al., forthcoming; Currie et al., 2007; Currie, 2009; Jhala et al., 2009; Healy et al., 2008). Often these machines are housed in smaller treatment rooms with lead lined walls to meet external shielding requirements. For some room designs this means that easily accessible external ports are not built for dosimetry purposes. Nor are their gaps under doors to fit cables. It may also not be feasible for some reason to retrofit/renovate the treatment room to add a dosimetry port. This leaves the physicist with no ability to extend their dosimetry equipment such as the electrometer to outside the treatment room during irradiation. This short note investigates the effects if the electrometers are left inside such a room and provides information of a shielding recommendation is this case occurs.

2. Materials and methods

A Farmer 2570 dosemeter was used for the radiation scatter study. A farmer 2571 thimble ionisation chamber was located inside an RMI solid water stack phantom with dimensions 30 × 30 × 30 cm for the dosimetric study. A Gulmay D300

* Corresponding author. Illawarra Cancer Care Centre, Department of Medical Physics, Crown St, Wollongong, N.S.W 2500, Australia. Tel.: +61 2 42 225 709; fax: +61 2 42 265 397.
E-mail address: martin.butson@sesiahs.health.nsw.gov.au (M.J. Butson).

1350-4487/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.radmeas.2011.01.008

orthovoltage machine was used with a 250 kVp x-ray beam using various square x-ray fields up to a size of 15 × 15 cm. Measurements were performed applying 100 cGy radiation dose to the D_{max} position using the IPEMB 96 (Aukett et al., 2005), protocol. The NE Farmer 2570 dosemeter was attached to a Farmer thimble 0.6 cc ionisation chamber for charge measurements. The applied voltage used was 300 V in either positive or negative polarity. The Farmer dosemeter was positioned at various points within the treatment room as well as outside the treatment room to observe any effects on measured charge induced by radiation scatter. The radiation exposure at the position of the dosemeter was measured using a Victoreen 451 survey meter and given in mSv/hr. A 4 mm thick lead shield was also used for some experiments to minimize scattered radiation. It was designed to encase the entire dosemeter except for the front panel in a box shape just larger than the electrometer itself. The relationship between measured charge readings, the radiation exposure rate at the site and position of the electrometer and the effects of lead shielding were all examined.

Table 1
Comparison of ionisation charge recorded deviation (using a single polarity), and exposure rate level.

Field size (cm)	Exposure level (cm)	Distance to phantom	% Deviation (Square.) (mv/hr)
4	2.5	120	0.3
4	12	80	0.9
4	23	30	1.4
4	42	8	2.5
6	3.5	120	0.4
6	15.5	80	1.2
6	31	30	1.6
6	53	8	2.6
10	6.0	120	0.4
10	20.5	80	1.1
10	65	30	3.3
10	115.5	8	7.5
15	12.5	120	0.8
15	34.5	80	1.9
15	113	30	6.7
15	186	8	17.2

3. Results and discussion

Fig. 1 shows a representative measurement of charge recorded using the farmer 2570 dosemeter and 2571 thimble ionisation chamber when the phantom was irradiated with 100 cGy applied radiation dose as the distance from the Dose meter to the phantom position was varied. The beam used was a 250 kVp x-ray beam with a 15 × 15 cm square field. Similar but smaller deviations were recorded at smaller field sizes. Results show a significant difference in the measured charge depending on the applied voltage (positive or negative) and the distance of the meter from the phantom. When the chamber voltage was positive a higher value for charge was measured and vice versa. A ±17.2% difference was measured with our electrometer as close as possible (8 cm) to the phantom and measurable differences (2%) were still seen at more than 1 m from the phantom. Significant differences were recorded when the electrometer was positions within 30 cm from the phantom as would be the normal case if the electrometers was placed on the clinical treatment bed with the dosimetry phantom. It should be noted however that the average value between positive and negative polarity at all positions displayed negligible differences and agreed with outside room measurement averages. This behaviour is analogous to the extra-cameral volume effects in ionization chambers and extension cables reported in radiation dosimetry.

Table 1 shows the measured percentage deviations above normal non-scatter induced polarity effects of results for a 250 kVp beam using various fields sizes and at different positions/distances from the phantom of the electrometer within the treatment room when using a single polarity. Also quoted is the measured exposure level at each site. Results indicated that the level of deviation is related to the scattered radiation exposure which varied with field size and room position. When the results are graphed in relation to exposure level, Fig. 2 is produced. This is the percentage deviation from the value measured outside the treatment room (where negligible scatter occurs) for the average of both positive and negative polarity. The magnitude of the variation is very similar for both polarities. When the dosemeter was position on the table next to the phantom during irradiation up to 17.2% error in measured charge/dose occurred. This was at an exposure rate of approximately 186 mSv/hr.

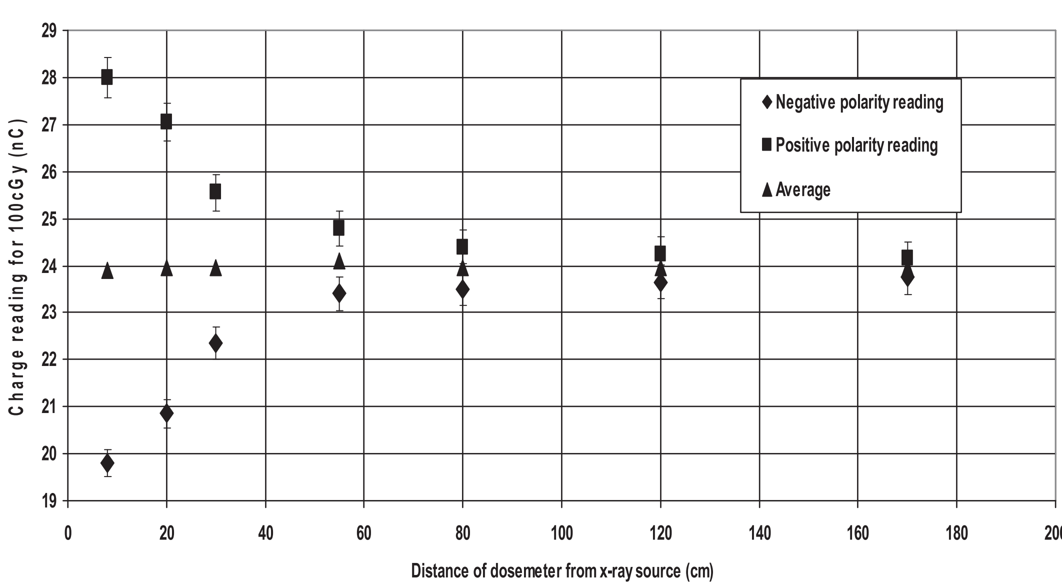

Fig. 1. Representative variation in measured charge for using an ionisation chamber and Farmer Dosemeter when the dosemeter is located within the treatment room and exposed to varying levels of scattered radiation.

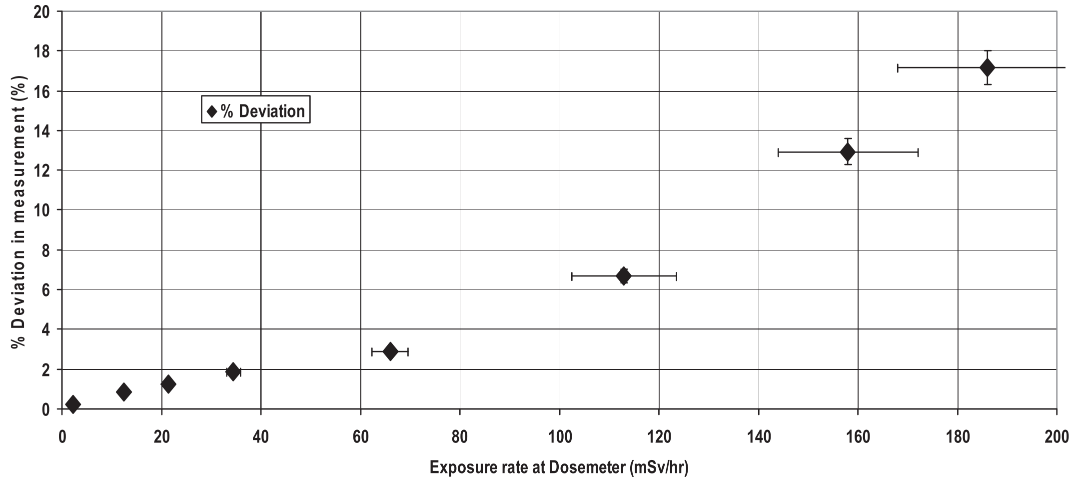

Fig. 2. Relationship between charge deviation and exposure rate for the 250 kVp x-ray beam.

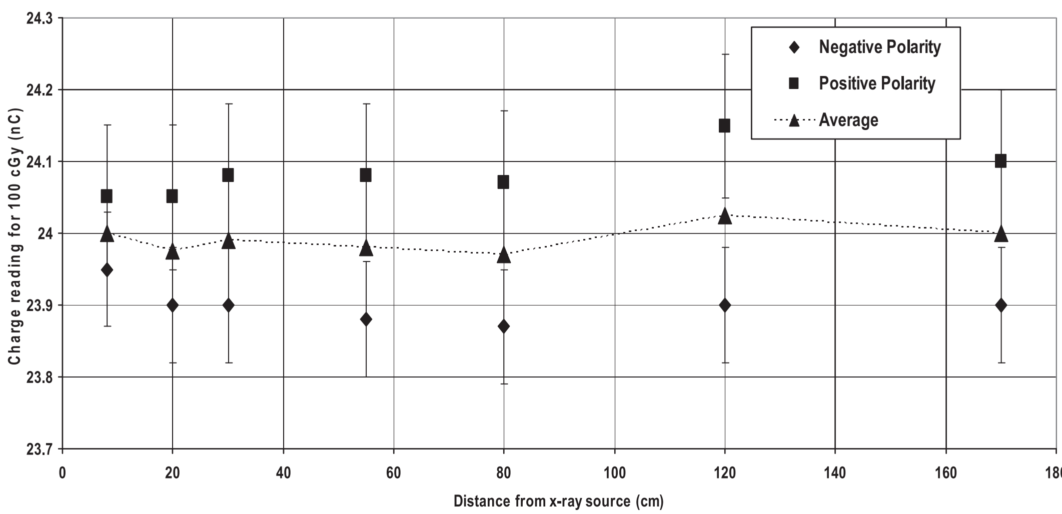

Fig. 3. Minimization of the radiation scatter deviation effect by the electrometer lead shield.

Fig. 3 shows similar results for Fig. 1 but when the dosemeter is shielded by a lead sheet around the device to minimize the impact of direct and indirect radiation scatter. As can be seen the lead (4 mm thickness) provides an adequate shield and appears to negate the effect of the scattered radiation. The differences seen in measured ionisation for positive and negative polarity are similar to that seen when measured outside the treatment room and are due to chamber polarity effects. Tests were not performed with differing thicknesses of lead shielding however it would be expected that the minimum thickness required could be calculated based on HVL measurements of the scattered radiation. As such it is recommended that a lead shield dome is used for orthovoltage and superficial radiation dosimetry for the dosemeter if it cannot be placed outside the treatment room during irradiation. It is also recommended to use polarity averaging for dosimetry if the electrometer has to be left inside the treatment room. Whilst it is common sense to not place a radiation electrometer next to the radiation source during x-ray dose assessment, it may be considered acceptable to locate the meter at a distance from the source which is as far as possible if no exit port from the treatment room exists. However, measurement of any radiation scatter at this point would need to be assessed along with any associated electrometer reading deviations before dose assessment is performed. It would be prudent if this case exists to construct and use a similar lead box shield for the electrometer to minimize scatter radiation and thus uncertainties it causes.

4. Conclusion

Scattered radiation from orthovoltage machines can have a significant effect on radiation dosimetry when using high voltage ionization chambers if the dosemeter is present inside the treatment room during irradiation. Up to $\pm$17.2% variation was measured in this study at 250 kVp. As such, it is recommended that a large lead shield be used around such a device if it is impossible to remove the dosemeter from the room during irradiation. This will minimize and hopefully eliminate variations in measured charge from different polarities used on the chamber during irradiation caused by scattered radiation. It is also recommended to use polarity averaging for dosimetry if the electrometer has to be left inside the treatment room.

Acknowledgements

This work has been fully supported by a grant from the Research Grants Council of HKSAR, China (Project No. CityU 100509).

References

Aukett, R.J., Burns, J.E., Greener, A.G., Harrison, R.M., Moretti, C., Nahum, A.E., Rosser, K.E., IPEM Working Party, 2005. Addendum to the IPEMB code of practice for the determination of absorbed dose for x-rays below 300 kV generating potential (0.035 mm Al-4 mm Cu HVL). Phys. Med. Biol. 50, 2739–2748.

Butson, M.J., Mathur, J., Metcalfe, P.E., 1995. Dose characteristics of a new 300 kVp orthovoltage machine. Australas. Phys. Eng. Sci. Med. 18, 133–138.

Butson, M.J., Cheung, T., Yu, P.K., Price, S., Bailey, M., 2008. Measurement of radiotherapy superficial X-ray dose under eye shields with radiochromic film. Phys. Med. 24 (1), 29–33.

Butson, M.J., Cheung, T., Yu, P.K., 2008. Measurement of dose reductions for superficial x-rays backscattered from bone interfaces. Phys. Med. Biol. 53 (17), N329–36.

Butson, M.J., Cheung, T., Yu, P.K., 2008 Sep. Measuring energy response for RTQA radiochromic film to improve quality assurance procedures. Australas. Phys. Eng. Sci. Med. 31 (3), 203–206.

Butson, M.J., Cheung, T., Yu, P.K., 2007. Radiochromic film for verification of superficial x-ray backscatter factors. Australas. Phys. Eng. Sci. Med. 30 (4), 269–273.

Cheung, T., Butson, M.J., Yu, P.K.N., 2009. Energy dependence corrections to MOSFET dosimetric sensitivity. Australas. Phys. Eng. Sci. Med. 32, 16–20.

Currie, M., Bailey, M., Butson, M., 2007 Jun. Verification of nose irradiation using orthovoltage x-ray beams. Australas. Phys. Eng. Sci. Med. 30 (2), 105–110.

Currie, B.E., 2009. Determining superficial dosimetry for the internal canthus from the Monte Carlo simulation of kV photon and MeV electron beams. Australas. Phys. Eng. Sci. Med. 32 (2), 68–80.

Healy, B.J., Sylvander, S., Nitschke, K.N., 2008. Dose reduction from loss of backscatter in superficial x-ray radiation therapy with the Pantak SXT 150 unit. Australas. Phys. Eng. Sci. Med. Mar. 31 (1), 49–55.

Jhala, E., Steer, B., Laban, J., Greig, L., 2009. Issues encountered with kilovoltage x-ray reference dosimetry when changing codes of practice from TRS 277 to TRS 398. Australas. Phy. Eng. Sci. Med. Mar. 32 (1), 11–15.

Kurup, R.G., Glasgow, G.P., 1993. Dosimetry of a kilovoltage radiotherapy x-ray machine. Med. Dosim. 18, 179–186.

Mondalek, P.M., Phillips, T.W., Randolph, E.G., Tolly, K.J., 1988. Design and beam characteristics of the Siemens Stabilipan orthovoltage unit for intraoperative radiation therapy. Med. Dosim. 13, 1–6.

Podgorsak, E.B., Gosselin, M., Evans, M.D., 1998. Superficial and orthovoltage x-ray beam dosimetry. Med. Phys. 25, 1206–1211.

Zarand, P., 1979 Mar. On output variations of therapeutic x-ray equipment. Strahlentherapie 155 (3), 200–203.