Radiation Physics and Chemistry 167 (2020) 108171

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

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

Comparison between Al_2O_3:C pellets and DIODEs for TSEB *in vivo* dosimetry using an anthropomorphic phantom

S.B. Almeida[a,*], D. Villani[a,*], R.K. Sakuraba[b], A.C.P. Rezende[b], L.L. Campos[a]

[a] *Radiation Metrology Center, Instituto de Pesquisas Energéticas e Nucleares – IPEN/CNEN, Av. Prof. Lineu Prestes, 2242 – Cidade Universitária, São Paulo, SP, Brazil*

[b] *Radiation Therapy Department, Hospital Israelita Albert Einstein, Av. Albert Einstein, 665 – Morumbi, São Paulo, SP, Brazil*

ARTICLE INFO

Keywords:
In vivo dosimetry
Al_2O_3:C
Silicon DIODEs

ABSTRACT

The Total Skin Electron Beam (TSEB) therapy is a technique that aims to provide skin surface homogeneous absorbed dose in order to treat cutaneous T-cell lymphomas, both for curative and palliative purposes with electron beams penetrating a few millimeters into the skin, reaching the affected parts without affecting internal organs. *In vivo* dosimetry has become an important role for the treatment of total skin irradiation within a rigorous quality assurance. The luminescent dosimeters, such as TLDs and OSLDs, have proven to be very useful for the verification of the dose distribution and prescribed for the patient as the dose may differ from place to place due to patient body geometry, overlapping of structures and asymmetries of the radiation field. Other routine *in vivo* dosimetry tool is the DIODEs and they as well help validating radiation therapy dosimetry. Al_2O_3:C OSL pellets manufactured and marketed by REXON Components and TLD Systems have already been characterized for TSEB applications. The aim of this work is to compare the performance of Al_2O_3:C OSL pellets from REXON to *in vivo* TSEB dosimetry with silicon DIODEs QEDTM detectors from Sun Nuclear (EUA) using an anthropometric phantom. Dosimeters and DIODEs were previously characterized for 6 MeV HDTSe- electron beams and then placed over an Anderson Rando® anthropomorphic phantom, evaluating the body dose distribution. The reference point of measurement was the umbiculous as recommended by formalism. The results showed that the Al_2O_3:C OSL pellets presented acceptable results, but some greater variation of the response in relation to silicon DIODEs were found due to its considerable rotational dependency.

1. Introduction

Total body irradiation (TBI) is an important radiotherapy technique that releases a dose of megavoltage photons, with uniformity of dose within 10% throughout the body of the patient. It is a technique used to administer large fields of radiation throughout the body. It is a complex treatment program for aplastic anemia, leukemia, lymphomas and other types of tumors that are combined with high doses of chemotherapy and used in the preparation for bone marrow transplantation (Habitzreuter, 2010). Patients usually perform the applications in the anteroposterior and postero lateral positions or latero lateral applications in the sitting position with the arms close to the trunk or supported on the knees in equal doses. Gantry angles depend primarily on the size of the treatment room and the positioning of the patient. It is relevant that, regardless of the irradiation position, patient comfort should be taken into account during application. The use of absorbers in regions of different thicknesses (head, arms, legs *etc.)* is usually necessary to standardize the dose distribution. The simplest method of calculation is to consider TBI as a large, irregular field with heterogeneities. For each region of interest, for example head, thorax, arms, *etc.* we must determine the amount of radiation scattered so that with the primary radiation we can determine the dose in the region through the tissue-air relationship (Scaff, 1997; Podgorsak, 2005; Khan, 2010; Nevelsky et al., 2017).

Another technique of radiotherapy is total irradiation of the skin that aims to treat widespread malignant lesions of the skin (Chowdhary et al., 2016). This type of treatment aims to irradiate the patient's entire skin evenly with large electron fields. This is a technique that aims to provide skin surface homogeneous absorbed dose in order to treat cutaneous T-cell lymphomas, both for curative and palliative purposes with electron beams penetrating a few millimeters into the skin, reaching the affected parts without affecting internal organs. (Report 23, AAPM, 1987; Kamstrup et al., 2015).

The irradiation of the whole skin (TSEB) was developed by Stanford University in 1950 and being introduced for the treatment of cutaneous T-cell lymphomas, since then, TSI was considered one of the best

* Corresponding authors.
E-mail addresses: sbipen@usp.br (S.B. Almeida), dvillani@ipen.br (D. Villani).

https://doi.org/10.1016/j.radphyschem.2019.02.030
Received 12 December 2018; Received in revised form 7 February 2019; Accepted 14 February 2019
Available online 15 February 2019
0969-806X/

techniques of treatment for various diseases confined to the skin (Park et al., 2014). Treatment is done with the patient standing on a turntable that allows a better utilization of the beam being irradiated by six double fields, making a rotation of 60° for each position (anterior, posterior and four oblique fields). Each field is constituted of two elements of the beam, in this way the patient is irradiated with two electron beams having an angulation of 20° with respect to the waist line, up and down.

The luminescent dosimeters such as TLDs and OSLDs have proven to be very useful for the verification of the dose distribution and prescribed for the patient as the dose may differ from place to place due to patient body geometry, overlapping of structures and asymmetries of the radiation field (Almeida, 2018). Other routine *in vivo* dosimetry tool is the DIODEs and they as well help validating radiation therapy dosimetry. Al_2O_3:C OSL pellets manufactured and marketed by REXON Components and TLD Systems has already been characterized for TSEB applications (Almeida et al., 2019). The aim of this work is to compare the performance of Al_2O_3:C OSL pellets from REXON to *in vivo* TSEB dosimetry with silicon DIODEs QEDTM detectors from Sun Nuclear (EUA) using an anthropometric phantom.

2. Experimental

2.1. Dosimetric materials

The Al_2O_3:C OSL dosimeters from REXON Components & TLD Systems Inc. (Beachwood, Ohio) were separated according to the repeatability within ± 5.0% and separated into six groups, five for dosimetric measurements and one background dose control. Silicon DIODEs QED detectors from Sun Nuclear (Melbourne, EUA) were used as well for performing the *in vivo* measurements (Fig. 1).

2.2. Dosimeters readout and annealing treatment

Before and after measurements, the Al_2O_3:C samples were submitted to optical annealing with 1.3 W of power lamp composed by 30 blue LEDs Ourolux® for 24 h and its readouts performed with a RISØ TL/OSL system, model DA20 from Dosimetric Materials Laboratory – LMD/IPEN (Fig. 2).

2.3. Irradiation systems

The ^{137}Cs 4 π geometry gamma irradiator (Activity of 38.11 GBq in 17 April 2014) from LMD/IPEN was used to screen the OSLDs repeatability into limits of response of ± 5.0%. For both DIODES and OSLDs the characterization for electron field beams were carried out using the High Dose Rate Total Skin electron mode (HDTSe-) and 6 MeV beam of the linear accelerator Varian Clinac 23EX (Varian Medical Systems, Inc., Palo Alto, California) from the Radiotherapy Center of the Hospital Israelita Albert Einstein (HIAE).

2.4. Characterization of the OSLDs

The TL dosimeters were characterized for the HDTSe-6 MeV electron beam of the Clinac 23EX. Irradiations were performed positioning all detectors between two polymethylmethacrylate (PMMA) plates 0.3 cm thick and depth of 1.30 cm obtained with solid water bolus for electronic equilibrium conditioning (Fig. 3). More details can be found in (Almeida et al, 2018).

2.5. Experimental set-up and irradiations

The simulation provided the conditions of treatment using simulator AldersonRando® anthropomorphic phantom arranged on a turntable and a large PMMA sheet of 0.5 cm thickness used to module the electron fields. The experimental set-up is shown in Fig. 4.

The OSLDs and Diodes were placed over different parts of the phantom, waistline and the abdomen point was used as reference (z_{Ref}) as recommended by AAPM's Report 23. The measurements were performed on alternate days, as reported by AAPM, allowing greater study of sub- and over-dosage. The Silicon DIODEs were used as reference and compared with Al_2O_3:C. The experimental results of the absorbed doses are presented as the average of three dosimeter measurements, and the error bars are the standard deviation of the mean. All calculations were performed using Microsoft Excel 2016 software. Measurements were expressed in cGy, as is commonly used by medical physicists in clinical applications.

3. Results

3.1. Performance tests and characterization of the OSLDs

The repeatability measurements were performed free in air at electronic equilibrium conditions placing the OSL samples between two 0.3 cm PMMA plates. Irradiation with absorbed dose of 5 mGy, readout and thermal treatments were repeated five times to screen the samples with repeatability better than ± 5.0%.

3.2. Treatment simulation

For treatment simulation, 470 MU were selected in the console control of the Varian Clinac 23EX to deliver 210 cGy to z_{Ref}. OSLDs and Silicon DIODEs were positioned at z_{Ref} and disperse in 8 other points throughout the anthropomorphic phantom to evaluate the whole-body dose distribution and compare the Silicon DIODEs results with the Al_2O_3:C Table 1 presents the obtained experimental results.

4. Discussion

The dose z_{ref} was irradiated with 210 cGy and the measured doses varied ± 3.9% and ± 3.8% for Silicon DIODES and Al_2O_3:C TLD-500 dosimeters respectively. DIODES were considered as reference dosimeter to compare with Al_2O_3:C TLD-500 dosimeters both dosimeters

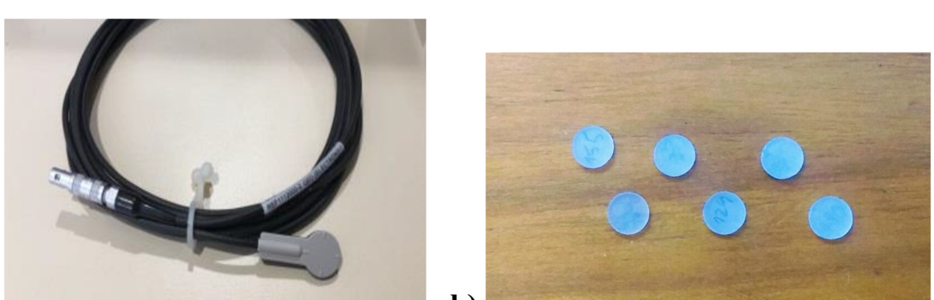

Fig. 1. (a) Silicon DIODEs and (b) Al_2O_3:C OSL dosimeters used in this study.

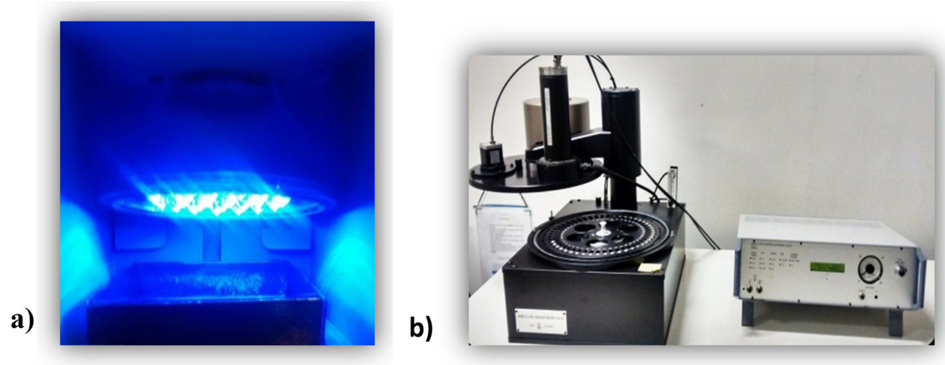

Fig. 2. a) Lamp composed by 30 blue LEDs Ourolux® and b) RISØ™TL/OSL reader.

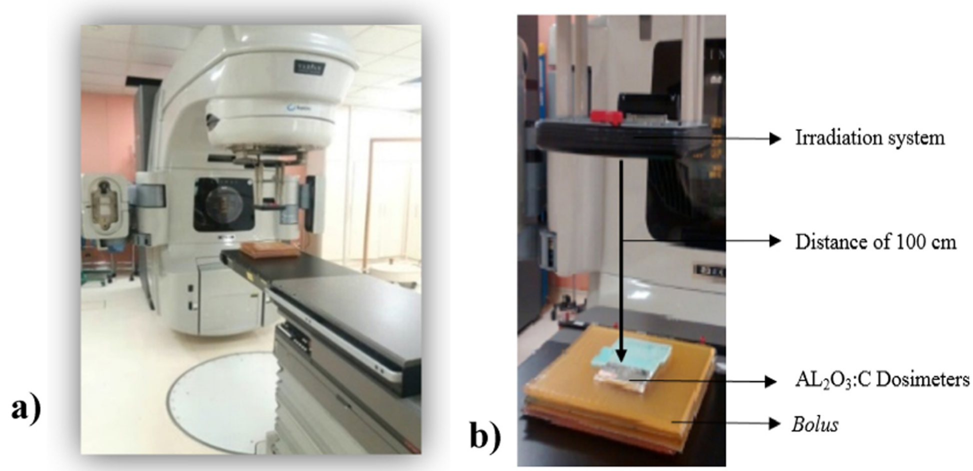

Fig. 3. Positioning of the dosimeters OSLDs between the two PMMA plates and irradiation; (b) set-up for dosimetric characterization with Varian Clinac 23EX.

Fig. 4. a) TSEB experimental set-up of irradiation using the AldersonRando® anthropomorphic phantom. Distance between the phantom and the field isocenter is 3 m and (b) location of AL_2O_3:C dosimeters and Silicon DIODEs.

measured absorbed doses varied up to 20% over the body surface due to anatomy of Alderson RANDO anthropomorphic phantom as predicted in formalism [Report 23, AAPM]. The large variations (~10%) found in measurements with the OSL detectors are probably associated with high angular dependence of the response reported in Almeida et al. (2018).

5. Conclusion

The results show that the Al_2O_3:C OSL pellets presented acceptable results, but some greater variation of the response in relation to silicon diodes were found probably due to its considerable rotational dependency. The use of Al_2O_3:C in the presented form (TLD-500) used in this study requires great attention to individual or batch sensitivity,

Table 1
TSEB treatment: delivered dose/irradiation positioning.

Positioning	Silicon DIODEs	σ (cGy)	Al_2O_3:C (cGy)	σ (cGy)	% Difference from DIODEs
Abdomen (Z_{REF})	202	14.2	218	14.8	7.9
Thorax Center	190	13.8	213	14.6	12.1
Thorax Right	195	14.0	201	14.2	3.1
Thorax Left	195	14.0	195	14.0	0.0
Posterior	196	14.0	204	14.3	4.1
Forehead	200	14.1	202	14.2	1.0
Scalp	162	12.7	178	13.3	9.9
Armpit Right	100	10.0	97	9.8	3.0

proper positioning for measurements and angularity. As expected, silicon diodes presented solid dosimetric results. Both dosimeters were found to be good for TSEB *in vivo* dosimetry, with the advantage of cable connectors for OSL dosimeters.

Acknowledgments

The authors would like to thank Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES (554/2018), Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq (142098/2017-5 and 573659/2008-7), CNEN and Fundação de Amparo à Pesquisa do Estado de São Paulo - FAPESP (2010/16437-0) for the financial support and to the radiation therapy staff of the Hospital Israelita Albert Einstein for the electrons irradiations.

References

Almeida, S.B., et al., 2018. TL and OSL dosimetric characterization of different luminescent materials for clinical electron beams application in TSEB treatments. J. Lumin. 198, 497–501.
Almeida, S.B., et al., 2019. Comparative study of the TL response of LiF: Mg, Ti and CaSO4: Dy in the clinical electron beams dosimetry applied to total skin irradiation (TSEB) treatments. Radiat. Phys. Chem. 155, 121–126. https://doi.org/10.1016/j.radphyschem.2018.05.025.
AAPM, 1987. Total Skin Electron Therapy: Technique and Dosimetry. (AAPM Report No. 23, Dic.).
Chowdhary, M., et al., 2016. Total skin electron beam therapy in the treatment of mycosis Fungoides: a review of conventional and low-dose regimens. Clin. Lymphoma Myeloma Leuk. 16 (12), 662–671.
Habitzreuter, A.B., 2010. Implementação da irradiação de corpo inteiro em radioterapia (Diss.). Universidade de São Paulo, São Paulo - Brazil.
Khan, F.M., 2010. The Physics of Radiation Therapy, 4 ed. Lippincott Williams & Wilkins, Baltimore, Maryland.
Kamstrup, M.R., et al., 2015. Low-dose (10-Gy) total skin electron beam therapy for cutaneous T-cell lymphoma: an open clinical study and pooled data analysis. Int. J. Radiat. Oncol. Biol. Phys. 92 (1), 138–143.
Nevelsky, A., et al., 2017. Room scatter effects in total skin electron irradiation: Monte Carlo simulation study. J. Appl. Clin. Med. Phys. 18 (1), 196–201.
Park, S.Y., AHN, B.S., PARK, J.M., YE, S.J., KIM, I.H., KIM, J.I., 2014. Dosimetric comparison of 4 MeV and 6 MeV electron beams for total skin irradiation. Radiat. Oncol. 9, 6.
Podgorsak, E.B., 2005. Radiation Oncology Physics: A Handbook for Teachers and Students/EB Podgorsak. International Atomic Energy Agency, Vienna, pp. 657.
Scaff, L.U.I.Z.A.M., 1997. Física da radioterapia 1 Sarvier, São Paulo.