Journal of Radiotherapy in Practice

cambridge.org/jrp

In-vivo dosimetry in Total Skin Electron Therapy: Literature review

Sundaramoorthy Dhivya[1], Chandrasekaran Anuradha[2], Venkatraman Murali[1] and Velayudham Ramasubramanian[2]

[1]Apollo Hospitals Chennai, Apollo Cancer Hospital, Department of Radiation Oncology, No.320, Anna Salai, Chennai 600035, Tamilnadu, India and [2]School of Advanced Sciences, VIT University, Vellore, India

Literature Review

Cite this article: Dhivya S, Anuradha C, Murali V, and Ramasubramanian V. (2021) In-vivo dosimetry in Total Skin Electron Therapy: Literature review. *Journal of Radiotherapy in Practice* **20**: 357–360. doi: 10.1017/S1460396920000369

Received: 20 March 2020
Revised: 27 April 2020
Accepted: 4 May 2020
First published online: 16 July 2020

Key words:
cutaneous T-cell lymphomas; total skin electron therapy; TSET guidelines; TSET in-vivo dosimetry; TSET treatment techniques

Author for correspondence:
Dhivya S, Apollo Hospitals Chennai, Apollo Cancer Institute, Department of Radiation Oncology, 320, Anna Salai, Chennai 600035, Tamilnadu, India. Phone: +91 8939650135.
E-mail: div.divya66@gmail.com

Abstract

Aim: Total Skin Electron Therapy (TSET) is a specialised radiotherapy technique to treat cutaneous T-cell lymphomas. The purpose of this article is to review different in-vivo dosimetry techniques and to identify further research direction in TSET

Materials and methods: Studies focused on in-vivo dosimetry in TSET were included. Studies based on absolute dosimetry in TSET were excluded and no restriction was applied regarding the type of treatment technique and the type of dosimeter.

Result: From the review of articles, we have found that obesity index and patient position during treatment plays a major role in underdose or overdose in TSET. Many studies favour individualised boost dose to patients. The analysis showed that thermoluminescent dosimeters are the most widely used dosimeters in TSET, and time-consuming is the only drawback in the use of dosimetry.

Conclusion: Study showed that the practice of using in-vivo dosimetry would be better way to treat TSET by ensuring accuracy of dose delivery to the patients. Further, only limited studies are available for dosimetry with radiochromic films. With this observation, we have started exploring the use of radiochromic film in our TSET dosimetry, and the results can be analysed to standardise the technique in future.

Introduction

Total Skin Electron Therapy (TSET) is a specialised radiotherapy technique to treat cutaneous T-cell lymphomas (CTCLs). T-cells (or T-lymphocytes) are a type of white blood cell of the lymphatic system that protects the body from infection and plays a vital part in the immune system. CTCL is a kind of non-Hodgkins lymphoma that directly attacks the body's T-cells and turns the cells malignant. The most common subtypes in the group of CTCL are mycosis fungoides and Sezary syndrome. These diseases can affect a particular area of skin or even the entire skin surface. So the treatment area for CTCL is always substantial in radiotherapy. The treatment modality is mainly based on the extent of the disease. Palliative cases are mainly treated with chemotherapy.[1–5] The cases defined to skin surface are treated with topical steroids, photochemotherapy and radiotherapy. CTCL has been treated by TSET since 1950.

TSET is a complex treatment procedure and differs from routine radiotherapy treatment techniques in patient's set-up, treatment distance and field size. It aims to deliver a uniform dose to the entire skin surface with maximal sparing of underlying tissue. Though dose uniformity is achieved, there can be some region in patient's skin which would be overdosed or underdosed. Hence, it is mandatory to monitor the accurate delivery of the prescribed dose during TSET through in-vivo dosimetry checks. The most widely used in-vivo dosimeters for TSET are thermoluminescent dosimeters (TLDs). Studies with other dosimeters such as radiochromic film, optically stimulated luminescence devices and metal–oxide–semiconductor field-effect transistors have been limited by low patient numbers[6]. Thus, the purpose of this article is to review different in-vivo dosimetry techniques and to identify further research direction in TSET.

Materials and Methods

Studies focused on in-vivo dosimetry in TSET were included. Studies based on absolute dosimetry in TSET were excluded and no restriction was applied regarding the type of treatment technique and the type of dosimeter. However, very few published TSET studies have been found and studies focused on in-vivo dosimetry are extremely rare, since TSET is a specialised and complex radiotherapy technique. Initially, our search was performed on recent studies. Later, the studies referred and cited in those recent studies were added.

CAMBRIDGE UNIVERSITY PRESS

Guidelines for TSET

As per European Organization for Research and Treatment of Cancer[7] recommendations, for the treatment of CTCL the required dose is 30–36 Gy. For healthy skin, the treatment dose of 36 Gy is tolerable; however, eye lens, toe nails and finger nails are to be protected with adequate shielding throughout the treatment. For sole of foot, the therapeutic dose is around 26–28 Gy. Generally, TSET should use low-energy electrons, assuring at the depth of 2 cm the dose should not exceed 20% of the prescribed dose. Also, the depth of 80% of dose absorbed should be not less than 4 mm. Hence, the electron energy for TSET can be chosen in the range of 4 MeV to 8 MeV, with the treatment distance ranging from 3 m to 8 m. The treatment duration may vary from 6 to 9 weeks depending on the prescribed dose. The daily dose should range from 1.0 to 2.0 Gy. The dose homogenity should be ±10% along both vertical and horizontal axes. The region of skin that receives less than 80% of prescribed dose should be enhanced with boost irradiation. Total photon contamination in electron beam should not exceed 0.7 Gy.

Treatment techniques

In the department of radiotherapy, TSET treatment can be performed by different techniques. The treatment technique in a specific hospital depends on several factors like available equipment, available treatment room size, electron beam energy, maximum field size, patient dimension and patient comfort.

The modified Stanford or 'six-dual-field' technique is commonly used to deliver TSET. The classic Stanford technique proposed by Karzmark[8] et al. uses four body orientations of a patient (one anterior, one posterior and two lateral positions). To acquire a better dose uniformity, this original technique was improved with six-dual-field technique by Page[9] et al. (six different position, positioned 60° apart around the circumference of the patient, each having a superior and inferior field).The classic rotational technique[10–13] has also been successfully used in many hospitals for TSET which involves continuous skin irradiation. In this method, the patient is placed on a rotating platform. An alternative method for classic rotational technique is rotary dual technique which is similar but using one dual field instead of single large field. Thus, whatever may be choice of treatment technique, the main intent of the treatment is to deliver a uniform dose to the entire skin surface with maximal sparing of underlying tissue.

Standing patient position

In 1995, Weaver[14] et al. performed in-vivo dosimetric study using TLD with 22 CTCL patients. All the patients were treated using a Stanford technique. In this study, the average dose to the flat surfaces of body such as umbilicus, forehead, sternal notch, mid-chest, mid-back was almost equal to prescription dose. In tangential surfaces of body, the average prescription dose was100% for lateral hip, 109% for inner thigh, 104% for calf and 97% for ankle. In thinner area of body, the average prescription dose was almost 80% for palm, hand and toes. In special area of body such as top of head, axilla and perineum, the study showed average prescription dose of 85%, 32% and 75%, respectively. For female patients, the average dose to inframamary fold was 40% of prescribed dose.

Similarly in 1998, Antolak[15] et al. performed in-vivo dosimetric study using TLD with 72 CTCL patients. All the patients were treated using a modified Stanford technique. In this study, the authors correlated data with patient's height, weight and obesity index. In each patient, the in-vivo dosimetry performed with 22 locations and for female patients, measurements were also performed in inframammary folds. The studies showed underdose in axilla, perineum, the tops of the shoulders, scalp vertex and soles of the feet and those sites was additionally boosted. The doses for the hand, abdomen and foot were less than 10% of the prescribed dose. The authors also compared their result with the Weaver et al. result and they mentioned the results were similar.

Recently Sarah[16] et al. performed in-vivo dosimetric study in TSET using TLD. The authors mentioned that their main aim was to review and to reduce the measurement sites based on their standard deviation and clinical importance. The authors also mentioned that due to the limitation of the TLD reader, the reading process was time-consuming. The measurements were performed with 27 locations and they grouped the location into trunk and extra trunk locations. The trunk locations includes nine points such as right and left anterior chest, mid-back, umbilicus, right and left lower back, anterior pelvis and right and left buttock. The rest 18 locations including head, neck, axilla, arm, thigh, knee, foot etc were grouped under extra trunk locations. Authors mentioned that the main aim of trunk dose measurement was to verify the prescription dose. The mean dose to nine trunk locations was 98.6% of the prescription dose and for extra trunk location was 93.6% of prescribed dose. From the dosimetric result, in trunk locations, the waist and both buttock points were showing duplicate information of other sites, since they placed closer to other points. In extra trunk locations, posterior neck and right elbow were showing duplicate information of other sites. The authors also mentioned that vertex, right shoulder and right upper arm points were intentionally shielded during irradiations and those points showing lesser dose. They also compared their result with both Weaver et al. and Antolak et al. results.

Reclined patient position

In 1989, Gerbi[17] et al. performed a study in TSET in reclined patient position. This technique is useful for patients either weakened by disease or those suffering from a loss of limbs. Authors mentioned that alike standard technique, this technique was not homogenous but the underdose was within the limits. They found difficult to compare their result with other studies.

Recently, Khaled Elsayad[18] et al. performed in-vivo dosimetric study using TLD with the data of 85 CTCL patients. The measurements were performed with TLD which includes both standing and reclining position of patient (standing, $n = 77$; reclined, $n = 8$) and the median number of measurements per patient was 20. Both techniques showed common underdose areas like axilla, sole and perineum fold. In standing position, the dose measured in axilla was 69% of prescribed dose, perineum folds was 20% of prescribed dose and soles was 34% of prescribed dose. Whereas in reclining position, the measured doses in all the above three sites were 1/3 of prescribed dose. Additionally, the authors correlated data with patient's weight and gender.

Rotary dual technique

Piotrowski[19] et al. performed in-vivo dosimetric study using TLD with the data of three CTCL patients. All the patients were treated using a rotary dual field technique. Rotary dual field technique use one dual field, and the patients were placed in rotating platform during treatment. In each patient, the in-vivo dosimetry performed with 34 locations. The authors also compared their result with earlier studies. They mentioned that since Weaver et al. suggested that

https://doi.org/10.1017/S1460396920000369 Published online by Cambridge University Press

there is a correlation between dose and height, they want to investigate furthermore. So, in this study, the authors compared their data with obesity index.

Result and Discussion

In Weaver[14] et al. study, the result showed that for flat surface, the dose was almost equal to prescription dose. For tangential surface, the dose shows larger variation. They justified that the variation was due to oblique patient position during treatment. The result showed that, for patient with thin thighs, the dose to 'inner thigh' was higher compared to patient with heavy thighs. In special sites such as top of head, perineum and axilla, the dose shows larger variation. In taller patients, the dose to 'top of head' was lesser compared to shorter patient. They justified that in taller patient, the top of head was closer to penumbra region of beam during treatment. Further, in inferior beam as well as posterior beam, top of head were partially shielded. While in shorter patient, all the six beams were tangential to the top of head. This results in higher dose to the top of head in shorter patients. They justified that the larger deviation in perineum and axilla was due to patient position during treatment. In female patients, dose to 'under breast' was lower for pendulous breast compared to smaller breast. The dose to dorsum of feet was 140% of prescribed dose, and the authors recommended for shielding after achieving prescribed dose.

Similar study of Antolak[15] et al. showed underdose area, such as axilla, perineum, the top of shoulder, scalp vertex and sole of feet. Analysis showed that the doses for the hand, abdomen and foot were 10% lesser than the prescribed dose. This is due to the reproducibility of positioning dosimeter on patients. They justified that the dose to axilla mainly depends on patient's ability to hold their arms during treatment. Also authors compared their data with patient's weight, height and obesity index. The analysis showed that the doses to abdomen and buttocks were mainly dependent on patient's obesity index. They justified that for obese patient, the source to surface distance (SSD) to umbilicus or buttocks increases for obliques beams compared to straight beams which cause a decrease in dose. The analysis shows that dose to mid-medial finger also depends upon obesity index of patients. The authors concluded that correlation for forehead, scalp, posterior medial neck, buttocks, abdomen and thighs with obesity index shows a significant result.

Recent study of Sarah et al.[16] also showed underdose commonly happening in regions like ankle, medial thigh and axilla. Authors compared their study with Antolak et al. and Weaver et al. and mentioned that all the dosimetric data were similar with the published results. On reviewing the dosimetric data, the authors removed sites showing duplicate information and high standard deviation. In trunk location, the measurement points reduced to 6 from 9 and in extra trunk locations, the measurement points reduced to 13 from 18 points. The authors also mentioned that this reduction would constitute a 25% time-saving in TLD preparation and reading process.

Alternatively, Khaled Elsayad[18] et al. study shows that both standing and reclined patient positions were dosimetrically heterogeneous. Authors have compared their result with obesity index. Analysis showed that in standing positions, the dose was significantly correlated with obesity index, whereas in reclined position, no significant correlation was observed. They justified that the dose variation in inner thighs, perineum and axilla was due to patient position and patient's parameters. So the authors commented that the boost dose should be individualised according to patient's response and clinical needs. They recommended that reduction in number of TLDs does not increase the risk of underdose. Further, they recommend routine use of in-vivo dosimeter in TSET as a part of QA programme.

In-vivo dosimetric study using TLD by Piotrowski[19] et al. shows the necessity for boost irradiation in the sites, such as scalp, hands, shoulders, perineum and feet. From the results, it is found that the boost dose to the underdosed area was dependent on patient's height and obesity index. So the authors suggested to prescribe boost dose for each patient depending upon the clinical need and patient's parameters. They also compared their data with earlier studies and they commented since their study was different from other studies, they found difficult in concluding the result. Interestingly, their result in axilla and top of shoulder shows inverse results from Stanford techniques. In Piotrowski[17] et al. study, the dose to axilla was 104–107% of prescribed dose, whereas in Stanford techniques the dose to axilla was almost 60%. Alterntively, the dose to top of shoulder was 55% in Piotrowski[17] et al. study, whereas in Stanford techniques the dose was almost 70%. Other sites like scalp, groin, abdomen, posterior neck, elbows, feet and hands were shown good agreement with Stanford techniques. The authors also investigated and accepted the comment made by Weaver[8] et al. that the height is the key factor in determining dose to the scalp. They also found good correlation between dose to obesity index in sites like shoulder, lateral neck, perineum and groin.

Based on the review of above articles, we have found that axilla, perineum and medial thigh are the common underdosed area in TSET. For female patients, inframammary folds were also underdosed. Most of the articles proved the correlation between dose with weight, height and obesity index. The study showed that doses to perineum, umbilicus and medial thighs were mainly depending on patient's obesity index. The doses to axilla, arm and top of shoulders depends on the patient position during treatment. The ability of the patients to maintain the arm position throughout the treatment decides dose to these regions. Thus, obesity index and patient position during treatment plays a major role in underdose or overdose in TSET. Many studies favour individualised boost dose to patients. So, by reviewing the dosimetric result along with clinical decision, we can decide the boost dose to different sites. Study showed that time-consuming is the only disadvantage of using TLD in in-vivo dosimetry, since the preparation and reading process with TLD take more time. Alternatively Sarah[16] et al. commented that reducing the number of TLD does not increase the risk of underdose. So depending upon the clinical need, department can decide the number of TLD measurements.

Conclusion

Thus, in-vivo dosimetry checks not only help to monitor dose but also to ensure beam calibration and monitor unit calculation. They give details about necessity of boosting the dose to the required sites and also information about shielding adequacy. So the practice of using in-vivo dosimetry would be better way to treat TSET by ensuring accuracy of dose delivery to the patients. From the review of articles, we have found that TLDs are the most widely used dosimeters in TSET, and time-consuming is the only drawback in the use of dosimetry. Whereas, preparation and reading process in radiochromic film were less time-consuming compared to TLD and it is more convenient. But only limited studies are available for dosimetry with radiochromic films. With this

https://doi.org/10.1017/S1460396920000369 Published online by Cambridge University Press

observation, we have started exploring the use of radiochromic film in our TSET dosimetry, and the results can be analysed to standardise the technique in future.

Acknowledgements. None.

References

1. Ramsay D L, Halperin P S, Zeleniuch-Jacquotte A. Topical mechlorethamine therapy for early stage mycosis fungoides. J Am Acad Dermatol. 1989; 10: 684–691.
2. Zackheim H S, Epstein E H, Crain W R. Topical carmustine (BCNU) for cutaneous T cell lymphoma: a 15-year experience in 143 patients. J Am Acad Dermatol. 1990; 22: 802–810.
3. Ramsay D L, Lish K M, Yalowitz C B, et al. Ultraviolet-B phototherapyfor early stage cutaneous T-cell lymphoma. Arch Dermatol. 1992; 128: 931–933.
4. Resnick K S, Vonderheid E C. Home UV phototherapy of early mycosis fungoides: long-term follow-up observations in thirty-one patients. J Am Acad Dermatol. 1993; 79: 73–77.
5. Roenigk H H. Photochemotherapy for mycosis fungoides. Cancer Treat Rep. 1979; 63: 669–673.
6. Guidi G, Gottardi G, Ceroni P, Costi T. Review of the results of the in vivo dosimetry during total skin electron beam therapy. Rep Pract Oncol Radiother 2014; 19: 144–150.
7. Jones G W, Kacinski B M, Wilson L D, et al. Total skin electronradiation in the management of mycosis fungoides: consensusof the European Organization for Research and Treatment of Cancer (EORTC) Cutaneous Lymphoma Project Group. J Am Acad Dermatol. 2002; 47: 364–370.
8. Karzmark C J, Lovinger R, Steele R E. A technique for large-field, superficial electron therapy. Radiology. 1960, 74: 633–643.
9. Page V, Gardner A, Karzmark C J. Patient dosimetryin the electron treatment of large superficial lesions. Radiology. 1970, 94: 635–641.
10. Kumar P O, Patel I S. Rotation technique for superficial total body electron beam irradiation. J Natl Med Assoc. 1978; 70: 507–509.
11. Reynard E P, Evans M D, Devic S, et al. Rotational total skin electron irradiation with a linear accelerator. J Appl Clin Med Phys. 2008; 9: 2793.
12. Podgorsak E B. Review of Radiation Oncology Physics: A Handbook for Teachers and Students. Vienna, Austria: I.A.E. Agency, 2003.
13. Piotrowski T, Malicki J. The rotary dual technique for total skin irradiation in the treatment of mycosis fungoides—a description of applied method. Rep Pract Oncol Radiother. 2006; 11: 29–37.
14. Weaver R D, Gerbi B J, Dusenbery K E. Evaluation of dose variation during total skin electron irradiation using thermoluminescent dosimeters. Int J Radiat Oncol Biol Phys. 1995; 33 (2): 475–478.
15. Antolak JA, Cundiff JH, Ha CS. Utilization of thermoluminescent dosimetry in total skin electron beam radiotherapy of mycosis fungoides. Int J Radiat Oncol Biol Phys. 1998; 40 (1): 101–108.
16. Misson-Yates S, Naeem M, Palmer I, et al. Total skin electron beam therapy rationalization and utility of in vivo dosimetry in a high-volume centre. BJR Open 2019; 1: 20190008.
17. Gerbi B J, Khan F M, Deibel F C, Kim T H. Total skin electron arc irradiation using a reclined patient position. Int J Radiat Oncol Biol Phys. 1989; 17: 397–404.
18. Elsayad K, Moustakis C, Simonsen M, Bäcker D, Haverkamp U, Eich H T. In-vivo dosimetric analysis in total skin electron beam therapy. Phys. Imaging Radiat Oncol. 2018; 6: 61–65.
19. Piotrowski T, Fundowicz D, Pawlaczyk M, Malicki J. Thermoluminescent dosimetry in rotary-dual technique of the total skin electron irradiation. Neoplasma 2003; 50 (2): 125–130.

https://doi.org/10.1017/S1460396920000369 Published online by Cambridge University Press