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Quantitative measurements for entrance and exit radiation dose confirmation for cancer patients: An analysis of large cohort of patients

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► ***Original article***

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ABSTRACT

Background: The success of radiation therapy depends on accurate dose delivery to the target. Diode in vivo measurement of entrance and exit dose is a valuable quality assurance (QA) tool to ensure accurate dose delivery. ***Materials and Methods***: This study was performed at BINO Cancer Hospital, Bahawalpur. Entrance and exit dose measurements were done with p-type diode for various types of cancer patients treated on Co-60 teletherapy unit. These measurements were compared with calculated (planned) dose values. A total of 3285 radiation fields of 723 cancer patients of various sites were included in current investigation. ***Results:*** The action level was ± 3 % for current measurements. The average percentage variation between the expected and measured dose was 0.37 with standard deviation 2.08. It was observed that 87.49 % of measurements were within tolerance level. It was also noticed that all dose deliveries fell within ± 5 %. This study showed that exit/wedged/oblique dose measurements were harder than entrance/non wedged/normal incidence dose measurements and more standard deviation were observed for these measurements. ***Conclusion:*** The Quantitative entrance and exit absorbed dose verification for cancer patients is beneficial for quality improvement in radiation therapy. A great majority of measurements were found within the acceptable limit. Execution of entrance and exit dose measurement procedure had demonstrated to be very helpful for detecting potential mistakes and avoiding errors due to accurate positioning of patients.

Keywords: *Cancer, dose verification, quality improvement, Co-60 teletherapy.*

INTRODUCTION

The aim of radiation therapy is to deliver tumoricidal dose to target while minimizing dose to surrounding healthy cells and organ(s) at risk as well. Radiation therapy is a chain like process posing a threat of error(s) at each step. The success of radiation therapy depends on accurate dose delivery to target. Diode *in vivo* measurement of entrance and exit dose delivery is valuable QA tool to ensure accurate dose delivery and quality of component processes.

Clinical dose verification is a key QA process and a safety tool for individual treatment of cancer patients and is recommended by various professional organizations [1-4]. Several cases of over exposure have been reported in literature [5-9]. These reports highlight the importance of dose verification during treatment to insure the quality of radiation treatment and to avoid the misadministration of radiation.

Guidelines for execution of entrance and exit

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dose measurement during delivery of radiation treatment to cancer patients are given by American Association of Physicists in Medicine (AAPM) [1] and European Society of Therapeutic Radiation Oncology (ESTRO) [2]. The effectiveness of *in vivo* dosimetry for detecting error(s) possibly skipped during pre-treatment check and results in patient over/under dose [10], is well documented. *In vivo* measurements are ultimate check to confirm the dose delivery during treatment of cancer patients [11, 12]. It can be performed by placing detector on skin or natural body cavities to detect error(s) in individual patient [4, 13].

The types of *in vivo* measurements include; entrance, exit and intra-cavitary measurements [4, 14]. Accuracy of patient's positioning and performance of radiotherapy machine including machine output can be checked with entrance dose measurements while that of dose calculation algorithm and effect of shape, size and variations of density within patient body can be detected by exit dose measurements.

This investigation is performed to check the potential use of the diode dosimeter to measure the entrance and exit doses of patients being treated on Co-60 radiation therapy unit. The utilization of diode detector for radiation dose verification in clinical radiation therapy has been reported in literature [15]. An entrance and exit dose measurement has been performed on various types of cancer patients at BINO Cancer Hospital, Bahawalpur.

The aim of this study was to measure delivered tumoricidal dose to improve the treatment accuracy, insure the quality of treatment and lessen the chances of dose misadministration. Data analysis for 3285 radiation field measurements of 723 cancer patients monitored during two years period, an analysis of large cohort of patients, is presented in this report.

MATERIALS AND METHODS

The gamma ray photons beam from cobalt-60 teletherapy unit (Phoenix, Theratronics International Ltd, Canada) was used for the treatment of cancer patients. These measurements were performed on various cancer patients treated at radiation therapy department-BINO Cancer Hospital Bahawalpur. Diode dosimeter system manufactured by Nuclear Associates, NY, USA was used for measurements of entrance and exit doses. The diode dosimeter was connected to a Patient Dose Monitor (PDM) electrometer manufactured by Nuclear Associates, NY, USA to measure the dose. The photon beam of Co-60 teletherapy machine was calibrated using an ionization chamber (Model N30013-03936, PTW, Freiburg, Germany) positioned at 5cm depth in water phantom according to the guidelines of International Atomic Energy Agency (IAEA) TRS-398 protocol [16]. Diode *in vivo* dosimetry system was calibrated as per procedure laid down in IAEA human health report 8 [4].

AAPM [1], ESTRO [2] and IAEA) [4] guidelines were followed for *in vivo* measurements. Diode was tightly taped on patient's surface in the central beam axis during radiation dose delivery as shown in figure 1. The diode dosimeter was fixed at suitable position in the radiation field avoiding to place it near edges closer than 2 cm in case(s) where it was not possible to place the diode detector in the center of the radiation field.

This study was part of the struggle to improve treatment quality and had been performed as per departmental protocol. This study was conducted after approval from Ethical Committee of BINO Cancer Hospital.

A spread sheet in MS Excel was developed for immediate and easy calculation of entrance & exit doses from the measured data and comparison with delivered doses at 0.5 cm & -0.5 cm from entrance & exit surface respectively. Percentage deviations between delivered and measured doses were calculated along with standard deviations. The action level ± 3 % for *in vivo* dosimetry of patients was set for this exploration. Statistical Package for Social Sciences (SPSS) version 16 was used for statistical data analysis. Endnote 5 was used for the management of references.

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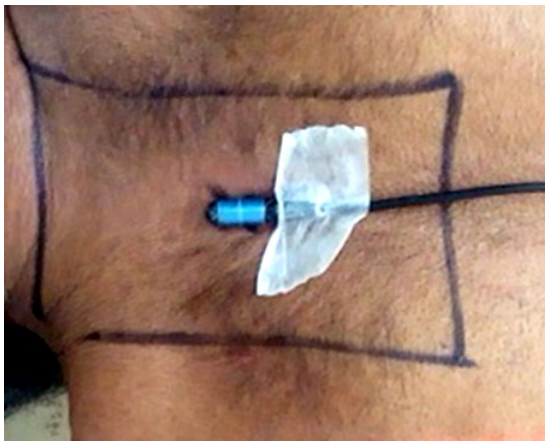


Figure 1. Diode dosimeter taped in the center of beam axis of radiation field.

Table 1. Demographic characteristics of patients.

Description	Male	Female	Total Patients	Fields Monitored	Dose/ Fraction (Gy)	Total Dose (Gy)
Spine	32	40	72	108	3	30
Thoracic	18	13	31	146	2	54
Abdomen	14	16	30	137	1.5 - 2	50
Face & Neck	201	183	384	1918	2	66
Head	60	79	139	590	1.8 - 2	54 - 60
Miscellaneous	39	28	67	386	2	60 - 70

RESULTS AND DISCUSSION

The current investigation was deliberated to explore the differences between the planned and measured doses for cancer patients treated on Co-60 teletherapy machine. Table 1 shows the demographic characteristics of patients monitored during current study. The results are presented as the variation between the measured dose and the calculated (delivered) dose articulated as a percentage difference of the calculated dose. Table 2 shows analysis of patients like number of measurements, number of patients, mean percentage difference as well as standard deviation for face and neck, head, thoracic, abdomen, spine and other miscellaneous sites respectively.

It was observed in this study that face and neck cancer is dominant followed by brain, thoracic, abdomen, and spine. The mean % deviation of all result remained within ± 0.4 % and mean standard deviation ± 1.97 %. These results are similar to previous results reported in literature [4, 14, 17-21]. There was no significant variation in results for different treatment sites like face & neck, brain, thoracic, abdomen, spine and other miscellaneous sites as presented in table 1.

The frequency distribution of the results expressed as relative variation of measured and calculated (entrance & exit) dose of cancer patients is depicted in figure 2.

It was observed (figure 3) that all data lies within ± 5 % and it is comparable to results reported in literature [4, 14, 17-21].

Table 3 shows the percentage of measurements that lies in two slabs i.e. ± 3 % and ± 5 % along with number of measurements.

The results showed that 86.91 % face & neck, 80.85 % head, 83.56 % thoracic, 94.16 % abdomen, 96.30 % spine and 83.16 % other miscellaneous sites were within tolerance level ± 3 %. The investigation of 3285 measurements demonstrated 87.49 % correctness in dose delivery i.e. within ± 3 % and these results are comparable with the published literature [4, 14, 17-21].

Overall 87.49% of the patients monitored in the present investigation were within the acceptable limits ± 3 %. 12.51 % measurements monitored in this study showed percentage differences more than the tolerance limits ± 3 %. It was observed in current investigation that all measurements were within ± 5 %. Although the action level in our institute was ± 3 % but for wedge and inclined fields, we accepted the data that was within ± 5 %. Patient setup/ movement/preparation, irregular body contours of treatment portal, tissue in-homogeneities, beam inclination, mistakes in data input to treatment machine and error(s) in dose calculation were possible reasons of large differences. Accurate placement of the dosimeter is a challenging task particularly for wedged and oblique field combinations. The reason seemed to be the failure in fixation of the diode perfectly

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in the center of radiation field. In a meticulous study performed, it was also noticed for a few measurements that the detector was somewhat dislodged due to slackening of the adhesive tape applied on it.

Only 53 measurements were required to be re-measured and the results of repeated measurements were found within tolerance limit. The re-measured results were included in this analysis. Table 4 shows the occurrence of errors along with their causes.

Table 2. Statistical analysis of results.

Description	Number of Measurements	Number of patients	Mean % Difference	Standard Deviation	Variance
Face and Neck	1918	384	0.37	2.06	4.260
Head	590	139	0.33	2.26	5.085
Thoracic	146	31	0.41	2.17	4.693
Abdomen	137	30	0.34	1.91	3.645
Spine	108	72	0.52	1.28	1.646
Miscellaneous	386	67	0.43	2.12	4.495

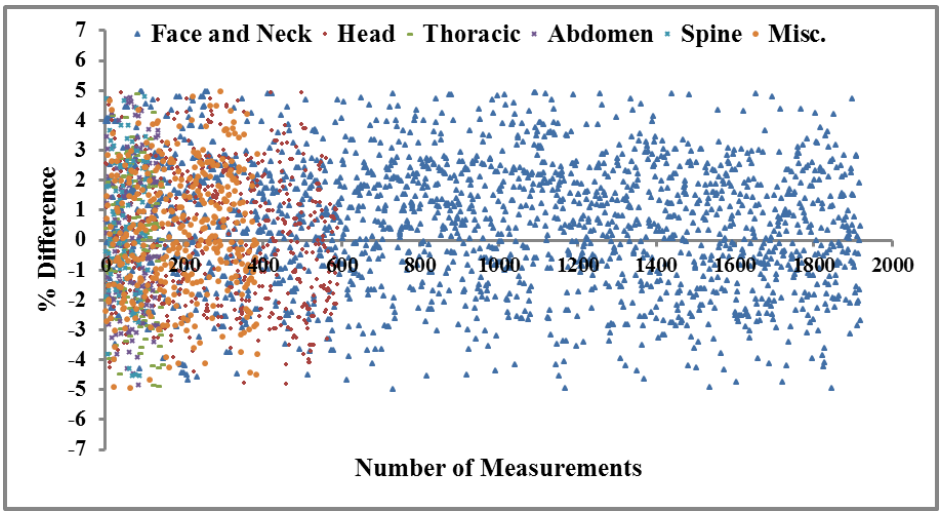


Figure 2. Percentage difference of measured and planned doses.

Table 3. Percentage of in vivo measurements that lies within ± 3 % and ± 5% of calculated dose.

Description	Face & Neck	Head	Thoracic	Abdomen	Spine	Miscellaneous
Number of measurements (N)	1918	590	146	137	108	386
measurements (N) within |Δ| ≤ ±3 %	86.91	80.85	83.56	94.16	96.30	83.16
% of measurements (N) for (± 3 % ≤|Δ| ≤ ± 5 %)	13.09	19.15	16.44	5.84	3.70	16.84

Table 4. Causes of errors for higher percentage difference observed during this study.

Number of fields	Reason for higher % difference
7	Wrong source to surface distance
7	Wrong wedge
3	Missing Wedge
6	Wrong field size
7	Incorrect dose
3	Elongated field
5	Irregular contour
15	Detachment of diode

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CONCLUSION

This clinical investigation showed that quantitative entrance and exit absorbed dose verification with diode dosimeter is beneficial for quality improvement in radiation therapy. Execution of entrance and exit dose measurement procedure has demonstrated to be very helpful for noticing potential mistakes and avoiding errors due to inaccurate positioning of patients. This study is part of the struggle to deliver the best quality treatment as per the national and international guidelines. It was observed that 87.49 % of the measurements fell within tolerance level (± 3 %) set in the institute. All measured data fell within ± 5 %.

Approval from Ethical Committee

This study was conducted after taking approval from BINO Monitoring and Ethical Committee of BINO Cancer Hospital, Bahawalpur, Pakistan.

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Conflicts of interest*: *Declared none.

REFERENCES

1. Yorke E, Ding L, Fontenla D, Kalend A, Kaurin D, Masterson -McGary ME, *et al.* (2005) AAPM, s TG-62 Diode *in vivo* dosimetry for patients receiving external beam radiation therapy. Report of task group 62 of Radiation Therapy Committee of American Association of Physicists in Medicine, published by Medical Physics Publishing. ISBN: 1-888340-50-9 (978-1-888340-50-9) and ISSN:0271-7344.
2. Huyskens DP, Bogaerts R, Verstraete J, Loof M, Nystrom H, Fiorino C, Broggi S, Jornet N, Ribas M,Thwaites DI (2001) Practical guidelines for the implementation of *In vivo* dosimetry with diodes in external radiotherapy with photon beams (entrance dose). Physics for Clinical Radiotherapy, 1st ed. Booklet No. 5. Brussels, Belgium.
3. Gadhi MA, Fatmi S, Chughtai GM, Arshad M, Shakil M, Rahmani UM, Imran MY, Buzdar SA (2016) Verification of absorbed dose using diodes in cobalt-60 radiation therapy. *Australas Phys Eng Sci Med, **39(1)**: 211-9*.
4. IAEA (2013) Development of procedures for *in vivo* dosimetry in radiotherapy, Human Health Report No. 8. Vienna, Austria.
5. IAEA (2001) Investigation of an accidental exposure of radiotherapy patients in Panama. Report of a Team of Experts,Vienna, Austria.
6. Derreumaux S, Etard C, Huet C, Trompier F, Clairand I, Bottollier-Depois JF, Aubert B, Gourmelon P(2008) Lessons from recent accidents in radiation therapy in France. *Radiat Prot dosimetry, **131(1)**: 130-5*.
7. Johnston AM (2016) Unintended overexposure of a patient during radiotherapy treatment at the Edinburgh Cancer Centre, S. Government, Scotland.
8. Williams MV (2007) Radiotherapy near misses, incidents and errors: radiotherapy incident at Glasgow. *Clinical Oncol, **19(1)**: 1-3*.
9. Opinion 16HDC00650 (2017) Auckland Radiation Oncology Limited, A Report by the Health and Disability Commissioner. https://www.stuff.co.nz/national/health/95769180/auckland-patient-given-double-the-correct-amount-of-radiation
10. Klein EE, Drzymala RE, Purdy JA, Michalski J (2005) Errors in radiation oncology: a study in pathways and dosimetric impact. *J Appl Clin Med Phys, **6(3)**: 91- 94*.
11. Van Dam J and Marinello G (2006) Methods for *in vivo* dosimetry in external radiotherapy. Physics for Clinical Radiotherapy. 2nd ed. ESTRO Booklet No. 1. Brussels, Belgium.
12. Higgins PD, Alaei P, Gerbi BJ, Dusenbery KE (2003) *In vivo* diode dosimetry for routine quality assurance in IMRT. *Med Phys, **30(2)**: 3118-23*.
13. Gadhi MA, Buzdar SA, Fatmi S (2016) *In vivo* dosimetry with diode for the treatment of pelvic malagnancies. *Austin Oncol Case Rep, **1(1)**: 1000-04*.
14. Evwierhurhoma OB, Ibitoye ZA, Ojieh CA, Duncan J (2015) Verification of entrance dose measurements with thermoluminescent dosimeters in conventional radiotherapy procedures delivered with Co-60 teletherapy machine. Ann Med Health Sci Res, **5(6)**: 409-12.
15. Costa AM, Barbi GL, Bertucci EC, Ferreira H, Sansavino SZ, Colenci B, Caldas LVE (2010) *In vivo dosimetry with thermoluminescent dosimeters in external photon beam radiotherapy. Appl Radiat Isot, **68(4-5)**:760-2.*
16. IAEA (2000) Absorbed dose determination in external beam radiotherapy: An international code of practice for dosimetry based on standards of absorbed dose to water; technical reports series No. 398. Vienna, Austria.
17. Pokoo-Aikins M, Acquah GF, Sackey TA, Boadu M, Hasford F, Dery TB, Schiestl B (2015) Accuracy of using *in vivo* dose verification with diodes for different sites. *Int J Sci Tech, **5 (1)**: 6-16*.
18. Mohammadkarim AR, Allahverdi M, Esfehani M, Nedaie H, Shirazi AR (2011) *In vivo* dosimetry evaluation of external photon treatments of brain, pelvis and breast cancer with

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diode dosimeters. *Bas Clin Can Res,* ***2****: 26-30*.
19. Morton JP, Bhat M, Williams T, Kovendy A (2007) Clinical results of entrance dose *in vivo* dosimetry for high energy photons in external beam radiotherapy using MOSFETs. *Australas Phys Eng Sci Med,* ***30(4)****: 252-9*.
20. Rodriguez ML, Abrego E, and Pineda A (2008) Implementation of *in vivo* dosimetry with Isorad semiconductor diodes in radiotherapy treatments of the pelvis. *Med Dosim,* ***33 (1)****: 14-21*.
21. Marzuki R, Rahman AA, Mustafa IS and Shabandi AN (2018) Diode dosimetric characteristics assessment for *in vivo* dosimetry in radiotherapy treatment. *J Phys Conf Ser,* ***1083(1)****: 1-6*.

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