ORIGINAL ARTICLE

In vivo dosimetry evaluation of external photon treatments of brain, pelvis and breast cancer with diode dosimeters

Alireza Mohammadkarim[1], Mahmoud Allahverdi[2,*], Mahbod Esfehani [3], Hasanali Nedaie [4]
Alireza Shirazi[4]

ABSTRACT

Background: Delivering the maximum dose to tumor while achieving the minimum dose delivery to normal tissue; is the most important goal in external radiotherapy. Diode in vivo dosimetry is widely considered to be an important tool for quality improvement of patient care in external radiotherapy. Uncertainty in dose delivery should fall within 5% of the prescribed dose as recommended by International Commission of Radiological Units and Measurement (ICRU).

Materials and methods: In vivo dosimetry was implemented for treatments of 36 pelvis and 38 breast cancer patients which were treated by 60Co photon irradiation and 38 brain cancer patients which were treated by 6MV photon irradiation. The diode dosimeters that were used in this study were two different models of PTW products, T60010L model was used for 60Co photon beam and T60010M model was used for 6MV photon beams.

Results: The frequency histograms of the relative difference between the expected and measured doses at breast, pelvis and brain treatments, have mean values and standard deviations of -1.21% (7.01%), -0.44% (4.06%) and -1.32% (5.08%) , respectively. Our study showed that the accurate prediction of the dose value at breast cancer treatment is harder than that at brain and pelvis cancer treatment and requires an estimation of the lack of scatter due to missing tissue.

Conclusion: Quantitative verification of the prescribed daily dose is important in external radiotherapy to ensure precision in patient set-up accuracy in dose delivery.

Keywords: External radiotherapy, in vivo dosimetry, Diode dosimeter.

1. Department of Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran.

2. Department of Medical Physics, Tehran university of Medical Science, Tehran, Iran.

3. Radiotherapeutic Oncology Department of Cancer Institute.

4. Department of Radiotherapy, Tehran university of Medical Science, Tehran, Iran.

4.Department of Medical Physics, Tehran university of Medical Science, Tehran, Iran.

Corresponding author:
telephone: +98 21 66948673, fax: +98 21 66482654.
Email: alahverdi@sina.tums.ac.ir

زمینه و هدف: رساندن حداکثر میزان اشعه به تومور همزمان با حداقل دریافت اشعه توسط بافت طبیعی مهمترین هدف در رادیوتراپی خارجی است. دیود دوزیمتری در محیط in vivo به صورت گسترده ای بعنوان ابزاری مهم در بهبود کیفیت مراقبت بیماران در رادیوتراپی خارجی مد نظر قرار گرفته است. میزان دوز دریافتی باید حداکثر ۵٪ دوز توصیه شده توسط کمیسیون بین المللی اندازه گیری و وسایل رادیولوژی باشد.

مواد و روشها: دیود دوزیمتری در محیط in vivo برای ۳۶ بیمار سرطان لگن و ۳۸ بیمار سرطان پستان درمان شده با ٦۰Co و ۳۸ بیمار سرطان مغز درمان شده با تابش اشعه ٦MV مورد استفاده گردید. در این مطالعه از دو مدل دیود دوزیمتر از محصولات PTW یعنی مدل T٦۰۰۱۰L برای ٦۰Co و مدل T٦۰۰۱۰M برای تابش اشعه ٦MV استفاده گردید.

یافته ها: تفاوت نسبی بین مقادیر مورد انتظار و اندازه گیری شده در بافتهای پستان، لگن و مغز به ترتیب دارای میانگین و انحراف معیار ۱.۲۱٪- (٧.۰۱٪)، ۰.٤٤٪- (٤.۰٦٪) و ۱.۳۲٪- (۵.۰۸٪) بود. ما نشان دادیم که پیش بینی دقیق مقادیر دوز در سرطان پستان مشکلتر از سرطان لگن و مغز است.

نتیجه گیری: اصلاح کمی دوز روزانه تجویز شده در رادیوتراپی خارجی به منظور اطمینان از دقت دوز تحویلی از اهمیت خاصی برخوردار است.

کلید واژه: رادیوتراپی خارجی، دوزیمتری در محیط in vivo، دیود دوزیمتر

Introduction

In vivo dosimetry by diodes is a reliable method for patient dose control. The major advantage of diode dosimeter compared with thermo-luminescent dosimeters (TLD) is that the results of the measurements are immediately available in diode dosimeter.[1-2] Uncertainty in dose delivery should in general, fall within 5% of the prescribed dose as recommended by the International Commission of Radiological Units and Measurements (ICRU).[3-4]

A routine diode in vivo dosimetry is based on a combination of prescribed and measured doses. The midline dose is defined as the measured dose value on the ray line halfway between the points of entrance and exit dose measurements.[5-7] In diode in vivo dosimetry at clinical radiotherapy, the midline dose is determined using only measured entrance and exit patient doses.[8] Calculation of midline doses were made using in vivo dosimetry protocols recommended by the ESTRO.[9-10]

Radiation treatment accuracy is expressed as a comparison between delivered and prescribed doses.[11-12] This study examined the reliability of the use of diode dosimeters for in vivo dosimetry and its usefulness as part of departmental quality assurance program.

Methods

All measurements were performed using T60010L diode (a model of P-type diodes for 1-5MV photon energies) and T60010M diode (a model of p-type diodes for 5-13MV photon energies). Investigations were performed using 60Co x-ray beams generated by Teratron 780-C 60Co treatment machine and 6MV x-ray beams generated by Varian Clinac 2100C. Diode dosimeters were calibrated against an ionization chamber system placed at the maximum depth dose inside a polystyrene phantom with a thickness of 15cm under reference physical conditions (field size=10×10cm2, SSD=80cm and SSD=100cm for 60Co and 6MV photon beams respectively, temperature=22.5oC). The entrance dose calibration factor was determined as the ratio of the absorbed dose measured by the ionization chamber at the build up

depth and the entrance semiconductor signal reading on the surface with a build up layer under reference conditions.[6,9-10,13] Also, exit dose calibration factor was determined as the ratio of the absorbed dose measured by the ionization chamber at the build down depth and the exit diode signal reading on the surface with a build up layer under reference conditions.[6, 9, 13]

The midline transmission (Tmid) was estimated as the ratio of absorbed dose measured at midline depth (Dmid) and absorbed dose that was measured at build up depth (Dm,en);[5-6] therefore

$$T_{mid} = \frac{D_{mid}}{D_{m,en}} = \frac{D_{mid}/D_{m,en}}{D_{m,en}/D_{m,en}} = (Percentage\ Depth\ Dose)_{mid} = PDD_{mid}$$

Also, Tmid was estimated as the ratio of absorbed dose at midline depth (Dmid) and absorbed dose at build down depth (Dm,ex) [5]; therefore

$$T_{mid} = \frac{D_{mid}}{D_{m,ex}} = \frac{D_{mid}/D_{m,en}}{D_{m,ex}/D_{m,en}} = \frac{(Percentage\ Depth\ Dose)_{mid}}{(Percentage\ Depth\ Dose)_{ex}} = \frac{PDD_{mid}}{PDD_{ex}}$$

To reduce the statistical error in the measurements, the midline dose was given by

$$D_{mid} = \frac{PDD_{mid} \times D_{en} + \frac{PDD_{mid}}{PDD_{ex}} \times D_{ex}}{2}$$

Where PDD corresponds to the percentage depth dose under reference conditions and Den and Dex are entrance and exit measured doses, respectively.[5]

In this study, for 36 pelvis and 38 breast cancer patients which were treated by 60Co photon irradiation, the midline dose was determined during her or his treatments. Also, we evaluated 38 patients with brain cancer who treated with 6MV x-ray beams and referred to radiation oncology department of Imam Khomeini hospital.

In clinical measurements, the placement of dosimeter on the entrance surface was made by a slight shift from the beam axis to avoid the shadow effect, but the exit diode was positioned along the beam axis.[4, 6]

The dosimetric quantity directly related to the treatment accuracy is the distribution of the dose delivered to the patient compared with the prescribed dose, defined as the percentage

$$\Delta(\%) = \frac{D_{meas} - D_{cal}}{D_{cal}} \times 100$$

Where Dmeas is midline measured dose and Dcal is prescribed calculated dose.

Results

The entrance and exit dose calibration factors for two model diodes used in this study were periodically checked. The calibration factors remained constant for the diodes, with negligible variation (±1%). Combined midline dose measurement values derived from midline transmission data with prescribed dose values have been performed on 112 patients (36 pelvis, 38 breast and 38 brain cancer patients). All pelvis patients were treated with SAD set-up by 60Co, all breast patients were treated with SSD set-up by 60Co and all brain patients were treated with SSD set-up on the 6MV linear accelerator. The results are plotted as histograms in **Figures 1, 2,** and **3**. Data are presented as the difference between the measured dose and the expected dose expressed as a percentage of the expected dose. Thus, a positive value indicates that measured dose was larger than expected and a negative value indicates that measured dose was smaller than expected.

Figure 1 shows the percentage deviation of measured midline doses from prescribed target doses in treatment of breast cancer. These data are well represented by a columnar distribution with a mean of -1.21% and a standard deviation of 7.01%.
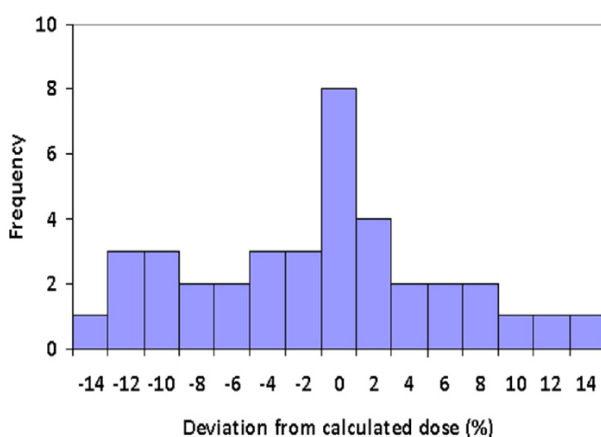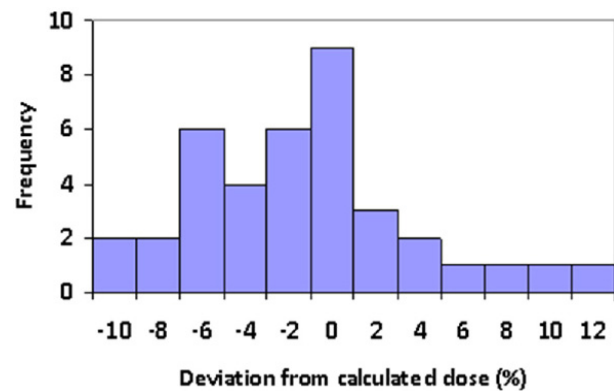

Figure 1- The relative deviation of measured midline doses from expected target doses as a percentage for the treatments of breast tumor

The histogram in **Fig. 2** shows the distribution of the discrepancies between measured and expected values for patient doses in treatment of pelvis cancer. Mean value of the distribution is -0.44% and standard deviation is 4.06%.
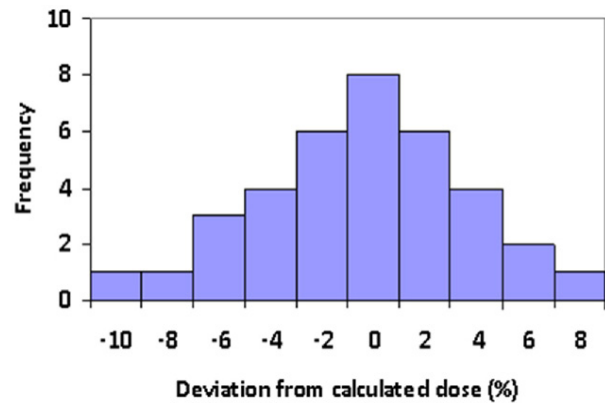
Fig. 2- The relative deviation of measured midline doses from expected target doses as a percentage for the treatments of pelvis tumor.

The frequency distribution of the relative difference of measured and expected midline dose in treatment of brain cancer is depicted in **Fig. 3**. Mean value of the distribution is -1.32% and standard deviation is 5.08%.

Fig. 3- The relative deviation of measured midline doses from expected target doses as a percentage for the treatments of brain tumor.

Discussion

Quantitative verification of the prescribed daily dose is of paramount importance during external radiotherapy to ensure precision in patient set-up and accuracy in dose delivery.

As mentioned before, comparing measured midline doses with due calculated doses, errors can be detected if the difference between measured and calculated doses is more than 5%.

Large errors detected in midline dose measurement, when comparing measured midline doses with calculated midline doses. Although there are a number of reasons responsible for such deviations, an apparent contribution is the inhomogeneities of tissues.

Large deviations, defined as a deviation larger than 5% from the expected midline dose, occurred in 47.4% (18/38) of measured treatment set-ups for breast cancer patients. Discrepancies larger than 5% from the expected midline dose have been detected in 22.2% (8/36) of measured treatment set-ups for pelvis cancer patients and deviations larger than 5% from the expected midline dose have been detected in 36.8% (14/38) of measured treatment set-ups for brain cancer patients. The standard deviation results at each organ presented here are approximately similar to those observed in previous papers.[14-16]

The result of breast cancer treatment showed larger standard deviation than the results of pelvis and brain cancer treatments (**Figs.1,2,3**). The large standard deviation at breast cancer treatments has to be ascribed completely to the lack of scatter due to missing tissue which is not taken into account in the dose calculation algorithm.

Some of the sources of errors are inaccuracies in algorithm, error in set-up, patient motion, error in contour determination, tissue inhomogeneities and error in placing diode.

The inherent measurement precision of the diode system is within 0.5%. The limiting factor on this, however, is the number of significant figures on the electrometer display, particularly for small measured signals. For entrance doses this is typically up to 1% and for exit doses typically up to 2%. However, particularly for small components of an overall irradiation (i.e. for very small diode readings), this limiting precision can be as high as 5%.[3]

Conclusion

In summary, this work described the methodology used and the results obtained in the implementation of an in vivo dosimetry method for patients receiving radiotherapy treatment of the breast, pelvis and brain cancer.

ESTRO in vivo dosimetry protocols were basically followed in the determination of midline doses from measurements of entrance and exit doses. The clinical results from this study are in agreement with other similar investigations published. From our study it can be concluded that diode in vivo dosimetry has a potentially significant role to play in the routine quality assurance of the delivery of radiotherapy and proving confidence in the delivery of treatment and in the identification of individual errors.

Acknowledgement

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