Original Article

Evaluation of Setup Errors in Two Radiotherapy Centers from a Physicist's Point of View

Keyvan Jabbari[1,*], and Nima Rostampour[1]

1- Department of Medical Physics, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran.

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ABSTRACT

Purpose- The setup verification is one of the important issues in radiation therapy. In this study, an experienced physicist evaluated the setup of the patients during treatments where many unexpected errors were observed.

Methods- The physicist spent few hours a week in the treatment room and recorded any error that happened in the treatment setup from the physicist's point of view. In some errors, a follow up dosimetry was performed to evaluate the effect of a specific error.

Results- The errors were divided into a few categories. Out of 1000 patients in a 3 years period, various minor and major errors were observed for 115 patients. Most of the errors were in treatment field's shape and size. There were also few mistakes made by technicians due to the lack of conceptual understanding particularly when the electron shield was placed too far from the skin. Results of film dosimetry revealed that this can cause a severe underdose of the tumor and an overdose of the shielded area.

Conclusion- Many of the recorded setup errors in this study were related to the setup protocols for a particular center. However, there are many mistakes such as mistakes of the technicians and physicists that can be prevented with proper trainings.

Keywords:

Radiotherapy,

Setup error,

Patient safety.

1. Introduction

The accuracy of the daily patient setup in radiation therapy is necessary in order to minimize the irradiation of normal tissues. Previous studies have shown that the tumor control probability (TCP) is largely dependent on radiation beam placements and proper implementation of treatment [1-5]. There are uncertainties in the planning and delivery of radiation. A small error in setup can lead to overdose of the normal tissues and under dose of the tumor. This leads to a treatment that deviates from the intended treatment.

The patient setup error is defined as the difference between the intended and the actual position of the patient and field shape. Errors during setup are divided into two kinds: systematic and random setup errors. The systematic error is a deviation from the values of mean displacement throughout the treatment course for all individual patients. The random errors represent day-to-day variation in the set-up of the patient. On the other hand, a systematic setup error occurs when a patient setup is done using incorrect positioning information such as misaligned lasers or light field. A random setup error occurs when the patient's position, internal position of the organ or field shape is incorrect. Therefore, the patient setup is related to human errors. Many tools have been developed for the inspection of various aspects of treatment setup in radiation therapy.

Corresponding Author:
Keyvan Jabbari, PhD
Department of Medical Physics, School of Medicine, Isfahan University of Medical Sciences, Hezar Jarib Street, Isfahan, Iran.
Tel: (+98) 3137929059
E-mail: jabbari@med.mui.ac.ir

Some clinical studies have used electronic portal imaging devices (EPIDs) or portal films [6-11]. With the use of EPIDs, it is possible to evaluate the online position of the patient relative to the radiation field. Recently, few studies have been carried out about setup errors in radiation therapy [4-6, 12-14]. The overall review of these studies and reports by physicist can prevent and minimize the set up errors in each center. Some of the errors are related to particular equipment and tools used in one center, however many of them are general mistakes that can happen in any radiotherapy center. Sometimes the possibility of legal suits for compensation by patients who are victims of such errors is a reason for not reporting. The errors can be considered as drawbacks of the treatment process in each hospital. Reporting of such errors can cause problems for a clinic and their staff, in this case complete anonymity, could be encouraging for voluntary reporting [2]. The overall results of these reports from various centers and the evaluation of the causes can reduce the rate of these errors.

The primary aim of this study was to assess and report the setup errors that have been observed at two radiotherapy centers in three years. The study started just as a simple evaluation of the treatment setup. However, many unexpected errors, containing dosimetric errors, were observed that motivated the authors to evaluate the causes closely and perform dosimetry and report it as the present work.

2. Materials and Methods

To evaluate the setup errors, a long term survey and analysis was performed in two radiotherapy centers. The evaluation was performed by an experienced physicist during the daily treatments. In this study, about 1000 patients were analyzed in their radiotherapy sessions during 2011 to 2014. The first center has two Neptune linear accelerators (Linac) with no MLC, and the other center is equipped with two Oncor Linacs from Siemens with 80 leaves MLC. Both centers have a treatment planning system. In the first center, most of the patients were treated with conventional techniques in which the radiation fields are planned using the simulator images and surface anatomical landmarks.

The physicist followed the technicians in the control room and treatment room during all steps of the setup and beam delivery. During each visit, all aspects of the treatment setup from physics point of view were checked. The evaluation by the physicist was performed with minimum interference in treatment time and setup. The setup errors were divided into nine categories:

1) Shielding: There were mistakes in photon and electron shields. An important error in shielding was due to improper placement of the shield by the technician. This occurred for the electron shielding, in which the technician used to place the electron shield far away from the patient skin, in a way that the shadow of the shield covers the shielded area (Figure 1). The electron applicators of Neptune Linac consists of lead blades in various distances from the surface. These blades enable one to place the extra shields in various distances from the surface. The distance of the shielding from the surface in this case was 20-40 cm from the patient's skin. This is totally due to the lack of conceptual understanding since despite photons, electrons do not move along a straight line from the source and electrons have a large lateral scattering [15]. It should be noted that the technician was aware of the fact that the electron shield should be placed close to the surface and this mistake was due to carelessness. This could cause two problems: overdose of the shielded normal tissue and underdose of the tumor [16-19]. The distance of the electron shield should not be more than 1 cm away from the skin. The setup for film dosimetry experiment for evaluation of this error is illustrated in Figure 1. In this experiment, three EDR2 films were placed on the surface of the PMMA phantom and the 3 shields were placed in 1, 20 and 40 cm distances from the surface according to the light field of the Linac. Each time 150 MU were delivered to the films.

2) SSD: This mistake was a simple carelessness of technician in the setup where the SSD of the patient was not matched with SSD in the patient's document.

3) Field size and field shape: First type of check for the field size was a simple check with a ruler on the patient skin and comparison of the size of the field in the physics calculation page. The possible source of the mismatch could be the wrong SSD (Source to Surface Distance) and depth of the tumor. Another type of the error was in the field shape of MLC which one leaf was left open by mistake at the time of treatment planning.

4) Bolus: This error was also due to a conceptual mistake of the technician about the application of the bolus. In few cases, the technician simply placed the bolus on patients head while there were large air gaps between the skin and the bolus (Figure 2).

5) Beam energy: This was also due to the carelessness of the technician. For example instead of 6 MV photons, 18 MV photons were selected. This mistake happens only in the manual treatments in which the treatment fields and setup are not exported automatically from the treatment planning system to Linac.

6) External objects within the radiation field: Many objects were inside the treatment fields including: jewelry, gold, necklace, and belt.

7) Monitor Unit (MU) calculation: Mistakes in the calculation of the MU which is related to carelessness of physicist. In one case, the physicist calculated the MU for 400 cGy dose instead of 200 cGy for each day. This was corrected from the second day of treatment.

8) Wrong treatment: Various wrong decisions observed, such as ignoring 13 sessions absence of the patient in the middle of the treatment course without any changes in the treatment.

9) Accidents: Few accidents were observed in the treatment room over the 3 years period of this study which are mentioned in the following sections.

The details of each error are documented and possible causes of the error were evaluated. Some of the errors were corrected during the course of the treatment.

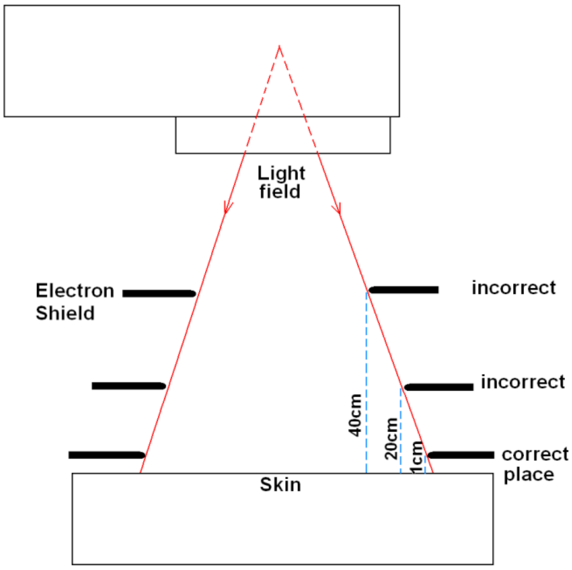

Figure 1. Illustration of the conceptual mistake for shielding of the electron fields. In the incorrect cases the electron shield is placed in large distances from the skin (20-40 cm) in the way that the shadow of the shield in the light field covers the shielded area.

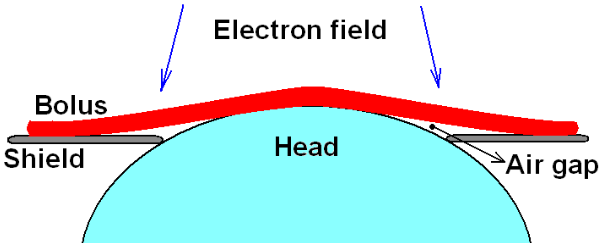

Figure 2. A sample of occurred error in using of bolus.

3. Results

In this study, 115 errors were recorded. This number includes all minor and major errors. Figure 3 shows the distribution of the errors for various categories. The maximum error types were related to field size (60 of 115 cases) and existence of external objects in the radiation field (26 of 115). The details and the consequences of the errors can be evaluated by calculation or measurements. Some of the consequences and causes of mistakes are evaluated as follows:

a) Impact of distance of shield placement in electron beams: In this error, the technician has placed the lead shield at the large distances up to 20-40 cm away from the surface of the skin in match with the light field of the Linac. The film dosimetry study determined the impact of this mistake as it is illustrated in Figure 4. The electron energy was 6 MeV and the type of films was Kodak EDR2. In these experiments the electron shields were placed at 1, 20, 40 cm away from the surface of the film while the shadow of the shield was in the correct position covering the shielded area (Figure 1). The films were calibrated, and dosimetry was performed according to Childress et al. recommendations [20-24]. Figure 4 illustrates the irradiated films and related isodose curves. This error causes the underdose of the treated area up to 50 % and it can also cause the overdose of the shielded area with an amount of 20% of the prescribed dose to tumor. It should be noted that this kind of mistake is not likely to happen in custom made electron shields in which the size and position of the shield cannot be changed. This can happen, for example, in a square field, the corner of which is supposed to be manually blocked with a simple lead block (Figure 4).

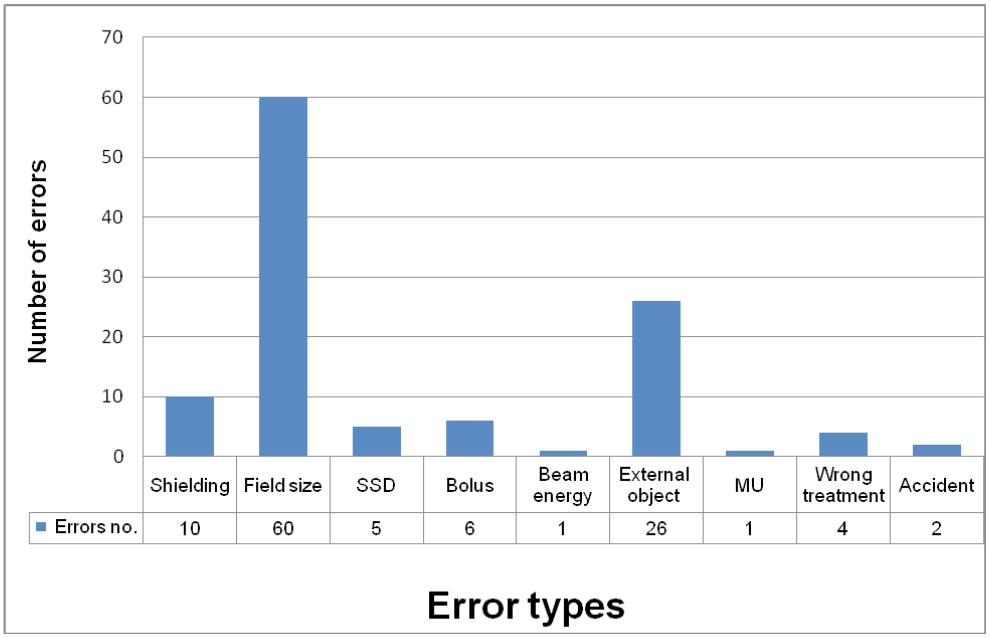

Figure 3. The distribution of the errors for various categories.

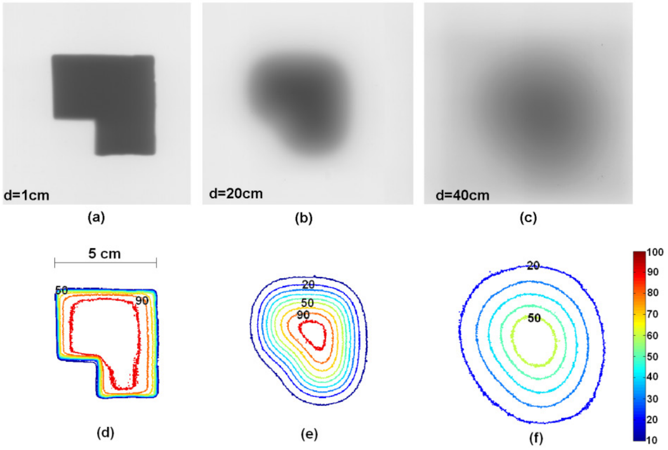

Figure 4. The results of film dosimetry for various cases in electron shielding. In Figures a, b, and c the electron shields were places in distances of 1, 20 and 40 cm from the surface, respectively. Figures d, e, and f illustrate the related isodose curves of the above films.

b) Air Gap under the bolus: The bolus is assumed to be in touch with the entire surface of the patient with no air gap. This error can cause the underdose of the skin since the bolus usually is used for superficial lesions to maximize the dose to the skin.

c) Error in MLC shape: An example of this mistake is illustrated in Figure 5. In this error, the jaws are not closed completely and they are not covering the borders of the MLC, therefore there might be an opening of the field by one leaf of MLC at the corners and out of the main field. The size of the un-wanted opening in Figure 5 is around 1×2 cm^2. This was the most common and unusual mistakes that were observed in this study. Searching for the reason for this mistake lead us to the way of the field illustration in the treatment planning system as illustrated in Figure 5. b. It should be noted that the hachure is added manually to Figure 5. b to illustrate the opening and the actual illustration is illustrated in Figure 5. a. The projection of the anatomy and the MLC leaves are all in a black background and the physician and physicist can easily miss the open spots in the plan. When the field is projected on the patient, since there is a light and dark shadow one can easily recognize an unwanted opening as illustrated in Figure 5. c. It should be noted that before this evaluation, for months technicians believed that these openings are part of the treatment field and no correction where made.

The worst case of error for MLC shape in this study was a 1×5 cm^2 field that was open right on the spine of a patient beside the main supraclavicular field. The patient was treated 12 sessions with this field. In order to solve this problem, all the technician were trained to inform the physicist upon the visiting of such an error to correct the field size. These cases included the MLC field shapes in which there were small open fields outside the main field, similar to the one shown in Figure 5. c. The number of these errors became lower after the proper training of the technicians about this error.

d) Accidents: In the first case, the technician, simply because of the typing mistake, entered 700 MU instead of 70 MU and this radiation was delivered to the patient. The technician realized the mistake in 350 MU and canceled the radiation. This accident was reported to the physicists later.

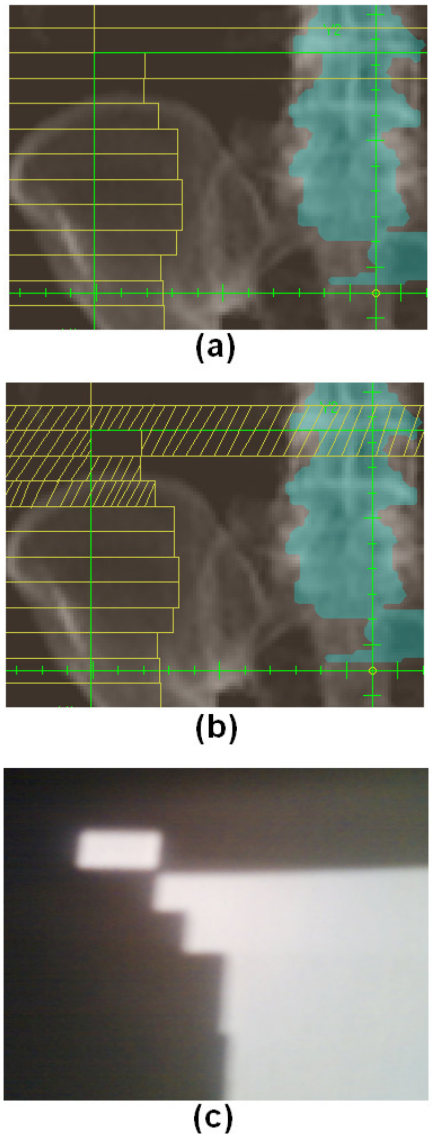

Figure 5. An example of error in MLC shape. a) This image illustrates how the radiation field looks like in the treatment planning software, where the error in the MLC shaping can easily be missed. b) The positions of the MLC leaves are hachured manually to illustrate the field shape. c) This is the shape of the field size on the patient's skin. The patient was "treated" over 17 sessions with this field size before the errors were observed and corrected.

In the second accident, the "z" bottom of the couch was sticky and was stuck while the technician was working with the couch and suddenly the couch started to move up. The breast board on the couch was crushed between the couch and applicators. No patients were on the couch and no injuries occurred.

The third accident happened in an old treatment room in which the changing space for the patient was inside the treatment room because of the lack of space in the center. In this accident, the technician did not notice that the last patient is still behind the curtain. After setting the patient and closing the treatment room, the Linac was turned on while the last patient was trapped in the room.

4. Discussion

The errors which were documented by physicist in this study had many different causes. Some of them were related to one particular radiotherapy center and the protocol of the setup in that center. The errors could have originated from various sources. 1) Physicist's mistake in calculation and chart checking, 2) Conceptual mistakes from technician and their carelessness, 3) Physicians mistake during treatment planning.

To minimize such errors, the recommendations that can be presented are:

1) A random check of treatment sessions by the physicist in each center may reveal many errors that need corrections. 2) The first treatment session of the patient should be checked by doctors which is a time consuming task. 3) The treatment session of each patient preferably should be scheduled with a fixed technician during the treatment period. 4) Placing two photos can help the technician to evaluate the patient setup in each session. One photo would be the actual picture of the patient in the position of the treatment with thermoplastic mask and proper markers. The second photo is generated by the physicist from the treatment planning software illustrating the first treatment field on the patient's anatomy or patient's skin. 5) Continuous training of the technician for possible causes of the errors. 6) The second check of physics calculation and plan is also a very important task. In both centers, the calculations and the chart of all patients are checked and signed by another physicist before the start of the treatment. All of the mentioned suggestions were employed in two studied centers and some errors such as the opening in MLC fields and errors in shielding field sizes were reduced considerably.

To evaluate the results of this work and accidents, it should be noted that the one center is using very old techniques of radiation therapy based on surface anatomical markers and simulator images. The data transfer in this center is also paper based in all steps of treatment. For example, when the field size of the patient is not transferred automatically to the Linac, as it is the case for old Linacs, every time that the technician manually sets the field size there is the possibility of a mistake. A similar example is the manual entry of the MU by technicians in which a simple typing mistake can lead to a wrong treatment. As mentioned before, in a recent accident the technician in the fourth field of a pelvis case, entered 700 MU instead of 70 MU. The technician realized the mistake in MU of 350 and canceled the radiation. This was in the last session of the treatment and the damage could not be compensated in further sessions. A powerful information management system such as LANITS or MOSAIQ in Siemens Linacs can eliminate this kind of error in plan transfer and dose delivery [25]. Many errors related to field size and MU entry can be avoided using such a system.

In modern techniques such as IMRT and VMAT, these kinds of errors are not likely to happen, however these methods are very complicated in all stages of planning and dose delivery. Therefore, different kinds of errors and accidents can happen employing these techniques [26-29]. These methods are generally based on highly conformed isodose surfaces to volume of the tumor, therefore any mistake in positioning of the patient or positioning of the tumor inside the patient can lead to underdose of the tumor.

In this study the setup of patients were evaluated by an experienced physicist during a 3 years period in two radiotherapy centers. The setup errors from the physicist point of view were recorded in details and possible causes of the errors were studied. This study showed that many unwanted errors could happen from various sources. Many of these errors are avoidable with proper training of the technician and making notes for physicians. Some of these mistakes are general and some errors are specific for a particular center and the protocol that they have for patient setup. Although some techniques such as digital portal images makes it possible to verify some accepts of the treatment verification, however this study highly recommends that a physicist at some points does a random check of the patient set up and treatment parameters.

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