Chapter one

Introduction:

1.1 Introduction:

Cancer is one of the leading causes of death globally and radiotherapy is currently an essential component in the management of cancer patients, either alone or in combination with surgery or chemotherapy, both for cure or palliation. In all radiation therapy a correct patient setup with reference to the treatment machine is important, since setup errors result in deviations from the planned treatment. The precision of the patient setup is even more crucial in Intensity Modulated Radiation Therapy (IMRT) since the dose distributions conform well to the intended target volume in the patient. To verify the patient position on the treatment couch, Portal Images (PIs) recorded during treatment can be compared to Digitally Reconstructed Radiographs (DRRs) DRRs are generated from the treatment planning CT-data. It is assumed that the patient setup error can be correctly represented by a 3D rigid transformation. In planning the treatment, the target volumes – containing the tumor and other areas that need to be irradiated – as well as the organs at risk (OAR) have to be defined and delineated in the CT data. To deal with inaccuracies, margins are generally added to the target volume. The goal is to deliver enough dose to the target while sparing the OAR. Room-mounted positioning lights are valuable aids for setting up patients who are undergoing radiotherapy. These lights are used during conventional or computed tomography simulation to place marks on the skin of patients or on their immobilization devices, so that the simulation geometry can be reproduced in the treatment room. The first positioning lights were similar to slide projectors: they used incandescent light bulbs to project a crosshairs onto the patient. Laser pointers soon replaced the original projectors,
because the resulting bright red dots were visible even under ambient light. Commercial devices now utilize that method, Concerning accuracy of lasers. (Ivan A. Brezovich, 2007)

1.2 problem of study:

The most important issue in radiotherapy of all organ is that evaluate uncertainties and determination of position setup. An analysis of patient setup errors resulting from inaccurately positioned wall lasers is presented. It suggests that laser beams should agree within 0.2° or better with the machine axes they are delineating. For typical simulator and treatment rooms, having wall-to-isocenter distances of 3 m, this requirement is satisfied when the beam emitting aperture is mounted within about 1.0 cm from the intersection of the respective machine axis with the wall.

1.3 objective of study:

The main objective of this study was to assess patient set-up errors in radiotherapy

1.3.1 Specific objective:

- To investigate patient set-up, tumor movement, shrinkage and breathing during 3D conformal radiotherapy for chest cancer
- To determine the magnitude of the errors made in the setup of patients with chest cancer on the simulator relative to their intended setup with respect to the planned treatment beams
- To determine the magnitude of the errors in the setup of these patients on the treatment unit
1.4 Overview of study:

This study falls into five chapters, chapter one, which is an introduction, it presents the statement of the study problems, objectives of the study, chapter two, contains the background material for the thesis, deals with quality assurance and patient positioning in radiotherapy. Chapter three deals with material and method. Chapter four deals with results and discussions. Chapter five conclusion, recommendations and references.
Chapter two

Literature review

2.1 quality assurance in radiotherapy:

According to recent studies by the World Health Organization (The World Health Report, (WHO, 1995), cancer incidence in the world is increasing rapidly, in both developed and developing countries. About 9 million new cancer cases are recorded each year, about 5 million of these in the developing world. The cancer incidence is projected by WHO to increase to approximately 15 million new cases by the year 2015. Two-thirds of these cases will occur in the developing countries. About 50% of cancer patients require radiation treatment, either curative or palliative. The urgent need for rapid worldwide expansion of radiation treatment technology demands mobilization of adequate resources, including the creation of new treatment facilities, particularly in the developing countries. Great progress has been made in the field of radiotherapy, in terms of higher levels of expertise and improvements in technology, including the introduction of modern therapy equipment (simulators, CT-scanners, modem teletherapy and brachytherapy units, computerized treatment planning systems, etc.). The rapid growth in radiation treatment methodology is thus followed by an increasing need for appropriate training of radiation oncologists, medical physicists, radiologists and radiation technologists. The implementation of modern technology can lead to continuous improvement in the outcome of treatment with respect to a high tumour control probability and a low rate of complications to normal tissue. On the other hand, because of its complexity, radiation treatment is subject to various sources of uncertainties, which may arise during different steps of radiotherapy chain, from dose prescription to dose delivery. In addition to inherent uncertainties in the planning and carrying out of treatment, there is a possibility of errors, including human mistakes and
equipment related problems, which can occur during the process of treatment. It is a known fact that many patients receive less than optimal radiation treatments, some being treated inadequately, with the increased probability of a lower cure rate or of severe complications. This problem concerns not only the developing countries without sufficient expertise or resources, but also several cancer centers in developed countries. The risk of inadequate radiation treatment can be minimized through the systematic execution of a comprehensive Quality Assurance (QA) program, which involves programmers for quality management and includes periodic quality control of equipment.

Major efforts have been made to develop and implement QA methodologies, aimed at reducing various sources of errors to ensure not only a high standard of radiation treatment, but first and foremost to prevent radiation accidents. Institutional QA programmes as well as inter-institutional programmes have to be implemented, together with audits by external reference national or international bodies. (Gerald J. Kutcher, TG Chair Comprehensive QA for radiation oncology April 1994)

Quality Assurance Program In Radiotherapy quality assurance of megavoltage beams and equipment is now well documented and applicable to every radiotherapy department. Present priorities are to implement quality assurance of beams and equipment world-wide on a prospective systematic basis - To check that once deviations are detected, corrections are made with proper follow-up measurements and audits. Proper implementation of quality assurance in radiation physics constitutes only one sector of the quality assurance programme in radiotherapy. Once the beam calibration is under control, the two weakest links of the radiotherapy processes are related to the physician and to the patient. The physician. The physician is responsible for ensuring proper interactions between different members of the radiotherapy team during the
planning and delivery of radiotherapy treatment Quality assurance can deal with the risk of errors which originate from the organization of the treatment process through a quality management programme. This programme evaluates inaccuracies resulting from the uncertainties of different parameters related to medical decisions (i.e. diagnostic procedures, tumour extension, margins of safety, etc.) and those resulting from the differences between prescription and the actual delivered treatment. A number of medical decisions (e.g. a definition of the planned target volume) may introduce risk for a larger uncertainty range in the treatment procedure than the uncertainties related to most of the dosimetry parameters.

The patient. The main risk of deviations in dose delivery may be attributed to the individual anatomical variations of different patients, to the reproducibility of patient positioning on the treatment couch, and to the control of patient movements during the treatment sessions. There is a general agreement that the entire process of radiotherapy, from diagnosis to delivery of treatment, should be subject to the dedicated and comprehensive quality assurance programmes.

This conclusion can be actualized by implementing the following recommendations:

- There is a need for every radiotherapy department to develop a programme for quality management of irradiated patients. Such a programme should describe the Responsibilities of every member of the radiotherapy team and should list the quality control procedures to be used in the department.

- Once the beam calibration is under control, the most important clinical parameter to measure is the outcome of the whole radiotherapy process (i.e. the dose delivered to the irradiated volume in a patient). The detection of a deviation in dose delivery will activate the revision of intermediate steps to locate the origin of the deviation(s). The main advantage of that method is to select cases at risk from a single procedure.
Radiotherapy is not the only discipline requiring the implementation of a quality assurance programme. Other disciplines involved in diagnosis (radiology, laboratories) and therapy (surgery, medical oncology) should develop similar programs. Two QA levels must be considered individually: the internal institutional level and the external independent multi-institutional (regional, national, international) level. A consensus has been reached recommending that the implementation of the quality assurance programme be carried out through a close interaction between the above two levels:

1- The internal institutional level. As previously mentioned, quality assurance should investigate every step of the radiotherapy procedure and involve all categories of the radiotherapy staff. The list of procedures, their timing, recording, reporting, and corrective processes should exist in a written format and be available for independent review.

2- The external independent multi-institutional (regional, national, international) level. (Margie Hunt, 1997).

The first consensus reached was on the need for minimum flexibility in the organization and structure of the external independent QA body, which must recognize national differences in competencies and structures in different countries. Metrology institutions can only check beam calibration and will not be able to carry out procedures on quality assurance of patients treated with radiation. Hence, it is strongly recommended that quality assurance programmes on the multi-institutional level dealing with beam calibration and/or beam quality checks be jointly coordinated by independent experts from both metrology institutions and radiotherapy departments. These external independent structures should naturally comply with the international recommendations and programmes (IAEA, ICRU).
These external independent structures should get a contractual recognition and/or legal administrative organization to be able to conduct quality assurance programmes on a systematic basis in every radiotherapy department in a given geographical area (region, country...). National programmes should define several levels of recommendations based on the level of standard practice in the individual countries. It is recommended to try to follow the general model of ICRU concepts (ICRU Report 50 [14]) and its 3 levels:

Level 1. Basic minimum requirements

Level 2. Reference level achieved by most representative institutions

(e.g. «the state of art » from expert's consensus)

Level 3. Research level

Quality assurance in radiation therapy includes those procedures that ensure a consistent and safe fulfillment of the dose prescription to the target volume, with minimal dose to normal tissues and minimal exposure to personnel.

A comprehensive quality assurance program is necessary because of the importance of accuracy in dose delivery in radiation therapy. The dare-response curve in radiation therapy is quite steep in certain cases, and there is evidence that a 7-10% change in the dose to the target volume may result in a significant change in tuner control probability . Similarly, such a dose change may also result in a sharp change in the incidence and severity of radiation induced morbidity. (WF Hanson, 1994).

2.1.1 Quality control:

Quality control is the regulatory process through which the actual quality performance is measured, compared with existing standards, and the actions necessary to keep or regain
conformance with the standards. Quality control is one part of overall quality assurance. It is concerned with operational techniques and activities used:

- To check that quality requirements are met;
- To adjust and correct performance if the requirements are found not to have been met. (WF Hanson - 1994).

2.1.2 Quality standards:

Quality standards is the set of accepted criteria against which the quality of the activity in question can be assessed. Various national or international organizations, such as the World Health Organization (WHO) in 1988, AAPM in 1994, European Society for Therapeutic Radiation Oncology (ESTRO) in 1995 and Clinical Oncology Information Network (COIN) in 1999, have issued recommendations for standards in radiotherapy. Other organizations, such as:

The IEC in 1989 and the Institute of Physics and Engineering in Medicine (IPEM) in 1999, have issued recommendations for certain parts of the radiotherapy process. Where recommended standards are not available, local standards need to be developed, based on a local assessment of requirements. (WF Hanson, et al 1994).

2.1.3 Need for quality assurance in radiotherapy:

An assessment of clinical requirements in radiotherapy shows that a high accuracy is necessary to produce the desired result of tumors control rates that are as high as possible, consistent with maintaining complication rates within acceptable levels. Quality assurance procedures in radiotherapy can be characterized as follows:
Quality assurance reduces uncertainties and errors in dosimetry, treatment planning, equipment performance, treatment delivery, etc., thereby improving dosimetric and geometric accuracy and the precision.

**2.1.4 Quality Assurance of External Beam Radiotherapy:**

409 of dose delivery. This improves radiotherapy results (treatment Outcomes), raising tumour control rates as well as reducing complication and recurrence rates.

- Quality assurance not only reduces the likelihood of accidents and errors occurring, it also increases the probability that they will be recognized and rectified sooner if they do occur, thereby reducing their consequences for patient treatment. This is the case not only for larger incidents but also for the higher probability minor incidents.

- Quality assurance allows a reliable inter comparison of results among different radiotherapy centers, ensuring a more uniform and accurate dosimetry and treatment delivery. This is necessary for clinical trials and also for sharing clinical radiotherapy experience and transferring it between centres.

- Improved technology and more complex treatments in modern radiotherapy can only be fully exploited if a high level of accuracy and consistency is achieved.

The objective of patient safety is to ensure that exposure of normal tissue during radiotherapy be kept as low as reasonably achievable (ALARA) consistent with delivering the required dose to the planning target volume (PTV).

This forms part of the objective of the treatment itself. The measures to ensure quality of a radiotherapy treatment inherently provide for patient safety and for the avoidance of accidental exposure. Patient safety is therefore automatically integrated with quality assurance of radiotherapy treatments.
2.1.5 Requirements on accuracy in radiotherapy:

Definitions of accuracy and precision as applied in a radiotherapy context, as well as discussions of dosimetric and geometric uncertainty requirements. In modern statistical analysis, uncertainties are classified as either type a meaning that they have been assessed by statistical means, or type B, meaning that they have been assessed by some other means. In earlier textbooks, and still in common practice, uncertainties are frequently described as random (a posteriori) or systematic (a priori). Random uncertainties can be assessed by repeated observations or measurements and can be expressed as the standard deviation (SD) of their random distribution. (DAVID I. THWAITES, 2001)

2.2. Patient Positioning In Radiotherapy:

CT simulators are CT scanners equipped with special features that make them useful for certain stages in the radiotherapeutic process. The special features typically are:

- A flat table top surface to provide a patient position during simulation that will be identical to the position during treatment on a megavoltage machine.
- A laser marking system to transfer the coordinates of the tumour isocentre, derived from the contouring of the CT data set, to the surface of the patient. Two types of laser marking systems are used: a gantry mounted laser and a system consisting of a wall mounted moveable sagittal laser and two stationary lateral lasers.
- A virtual simulator consisting of software packages that allow the user to define and calculate a treatment isocentre and then simulate a treatment using digitally reconstructed radiographs (DRRs).

A CT simulator essentially obviates the need for conventional simulation by carrying out two distinct functions:
Physical simulation, which covers the first three of the six target localization

Virtual simulation, which covers the last three of the six target localization

In CT simulation the patient data set is collected and target localization is carried out using CT images with fluoroscopy and radiography replaced by DRRs. A laser alignment system is used for marking and a virtual simulator software package is used for field design and production of verification images. Transfer of all necessary information to the TPS is achieved electronically. The planar simulation X ray film provides a beam’s eye view (BEV) of the treatment portal but does not provide 3-D information about anatomical structures. CT, on the other hand, provides anatomical information and target definition but does not allow a direct correlation with the treatment portals.

A DRR is the digital equivalent of a planar simulation X ray film it is reconstructed from a CT data set using virtual simulation software available on a CT simulator or a TPS and represents a computed radiograph of a virtual patient generated from a CT data set representing the actual patient. Just like a conventional radiograph, the DRR accounts for the divergence of the beam.

2.2.1 Treatment machine for external beam radiotherapy:

The basic approach to producing a DRR involves several steps: choice of virtual source position; definition of image plane; ray tracing from virtual source to image plane; determination of the CT value for each volume element traversed by the ray line to generate an effective transmission value at each pixel on the image plane; summation of CT values along the ray line (line integration); and grey scale mapping. An extension of the DRR approach is the digitally composited radiograph (DCR), which provides an enhanced visualization of bony landmarks and soft tissue structures. This is achieved by differentially weighting ranges of CT numbers that
correspond to different tissues to be enhanced or suppressed in the resulting DCR images. (Eb Podgorsak 2010).

2.2.2 Patient alignment laser:

Reliability, Stability and outstanding line quality are the hallmarks of fixed laser. Fixed lasers width of less than 1 mm at isocenter and a line depth of field 1.5 m- 4m. This ensures radiotherapy technicians precisely mark patients for therapy and reproduce position throughout a treatment schedule. Figerstrip controls provide independent adjustments for the angle of rotation of cross-lines. All fixed lasers include a custom-designed mounting plate (Figure 2.1).

![Figure (2.1) Shows Laser Positioning System](image)

2.2.3 Patient treatment position and immobilization devices:

Depending on the patient treatment position or the precision required for beam delivery, patients may or may not require an external immobilization device for their treatment. Immobilization devices have two fundamental roles:

- To immobilize the patient during treatment.
● To provide a reliable means of reproducing the patient’s position from simulation to treatment, and from one treatment to another. The simplest immobilization means include masking tape, Velcro belts or elastic bands. The basic immobilization device used in radiotherapy is the head rest, shaped to fit snugly under the patient’s head and neck area, allowing the patient to lie comfortably on the treatment table. Shows common headrests used for patient comfort and immobilization during treatment. Modern radiotherapy generally requires additional immobilization accessories during the treatment of patients.

Figure 2.2 immobilization accessories using for patient positioning and immobilization.

Patients to be treated in the head and neck or brain areas are usually Immobilized with a plastic mask that, when heated, can be molded to the patient’s contour. The mask is affixed directly on to the treatment table or to a plastic plate that lies under the patient, thereby preventing movement. a custom immobilization mask is shown in Fig. for treatments to the thoracic or
pelvic area, a variety of immobilization devices are available. vacuum based devices are popular because of their reusability. basically, a pillow filled with tiny Styrofoam balls is placed around the treatment area and a vacuum pump evacuates the pillow, leaving the patient’s form as an imprint on the pillow. The result is that the patient can be positioned snugly and precisely on the pillow prior to every treatment. another system, similar in concept, uses a chemical reaction between reagents in the pillow to form a rigid mould of the patient. Special techniques, such as stereotactic radio surgery, require such high precision that conventional immobilization techniques are inadequate. In radio surgery, a stereotactic frame is attached to the patient’s skull by means of screws and is used for target localization, patient set-up on the treatment machine and patient immobilization during the entire treatment procedure. The frame is bolted to the treatment table, thereby providing complete immobilization during the treatment.

Rigid immobilization of patients and accurate positioning of their targets have long been recognized as critically important aspects of quality radiotherapy. Radiobiological studies have indicated that the slope of the dose-response curve for many tumors is sufficiently large that a dose reduction of 3% to 5% to a portion of the tumor could significantly reduce the probability of local control. On the other hand, accurate positioning combined with rigid immobilization might permit reduced margins around the target, resulting in a decrease in dose to normal tissue and a potential increase in dose to the target. The increasing use of computed tomography-based three-dimensional treatment planning programs has made highly conformal dose distributions possible, thus further emphasizing the need for accurate positioning. The development of new immobilization materials and methods has made it possible to immobilize almost any area of the body of a cooperative patient to 3 mm, allowing the use of margins of no more than 5 mm except when target motion within the immobilized patient is an issue. Special techniques for intracranial
targets or for targets in the head and neck can yield positioning accuracies of 1 to 2 mm, or even less for invasive immobilization.

Through the use of electronic portal imagers, stereo video cameras, or stereo radiography, anatomical reference points can be followed during treatment and the target position varied as needed. Quantitative positioning studies are required for each disease site and immobilization method so that the target position uncertainty, which is the basis for the choice of treatment-planning margins, can be minimized and evaluated, leading to an increased level of uncomplicated local tumor control.

We have developed a number of immobilization schemes which permit precise daily positioning of patients for radiation therapy. Pretreatment and post-treatment radiographs have been taken with the patient in the treatment position and analyzed to determine the amount of intra treatment movement. Studies of patients in the supine, seated and decubitus positions indicate mean movements of less than 1 mm with a standard deviation of less than 1mm. Patients immobilized in the seated position with a bite block and a mask have a mean movement of about 0.5 mm +/- 0.3 mm (s.d.), and patients immobilized in the supine position with their necks hyper extended for submental therapy evidence a mean movement of about 1.4 mm +/- 0.9 mm (s.d.). With the exception of those used for the decubitus position, the immobilization devices are simply fabricated out of thermoplastic casting materials readily available from orthopedic supply houses. A study of day-to-day reproducibility of patient position using laser alignment and pretreatment radiographs for final verification of position indicates that the initial laser alignment can be used to position a patient within 2.2 mm +/- 1.4 mm (s.d.) of the intended position. These results indicate that rigid immobilization devices can improve the precision of radiotherapy,
which would be advantageous with respect to both tumor and normal tissue coverage in certain situations.

2.3. Patient set-up errors in radiotherapy:

The ultimate overall goal of radiotherapy is to deliver a specified radiation dose to the prescribed target volume with the least dose to healthy tissues. This means a sophisticated balance between the cure of the illness and the possibility of radiation induced complications. The demands for precision and accuracy are high, because very often a small increase in radiation dose will have crucial influence on the probability of a cure but simultaneously the probability of induction of irreversible damage to the patient will increase. An "error" is any deviation between the given numerical value of a quantity, such as the dose at a point or the position of a point, and its "true" value. In radiotherapy, errors may arise from at least four main sources: (i) human mistakes caused by inattention, misunderstanding or misjudgment; (ii) instrumental mistakes caused by mechanical or electrical failure; (iii) random errors due to unknown and/or uncontrolled experimental conditions in the process involved in the planning and delivery of radiation; and (iv) systematic errors, i.e. biases, in the same set of processes. In the following discussion, mistakes will be considered separately from the random and systematic errors. In principle, mistakes can be eliminated completely by a proper system of cross-checks of both human and instrument performance (by quality assurance system), although, in practice this may prove very difficult and expensive. random and systematic errors, on the other hand, cannot be eliminated but the magnitude of these uncertainties can be reduced by accumulation of better data and improved techniques of measurements and delivery of radiation. treatment process assumes simulation is representative of the average target position and that daily position is reproducible In reality there is positioning variability due to:
- bony anatomy set-up error
- internal organ position
- machine parameters compensated for by using generic population based margins from CTV to PTV studies show that using treatment verification reduces errors and allows the use of smaller population based margins in that department

Types of error:
- Systematic error
  - generally introduced at planning and therefore propagated throughout Treatment Patient moving between CT scan and marking tattoos
- Interobserver variability in contouring
- Pb/MLCs in wrong position
- planning and treating the wrong site
- Random error
  - Daily variable movements – internal and external!
  - Mis-interpreting set-up instructions
  - Worse in prone, overweight or poorly immobilized patients
- Critical if delivering short hypo fractionated treatments

2.3.1. Correction Strategy:
- Systematic errors
  - 3 - 10mm tolerance dependant on site
  - 75% of average error measured over at least 2 Fractions corrected
- Random Errors
2.4. Measurement of patient position error:

Radiotherapy of cancers is a complex multistep process from beam calibration to verifications during treatment. Each step includes measurement uncertainties, risks of systematic and occasional deviations. The final step, the treatment of the patient, incorporates the sum of all deviations added to the potential errors specific to this ultimate event. Sources of error in radiation therapy include tumor localization, lack of patient immobilization, field placement, and human errors in calibration, calculation, daily patient setup, and equipment-related problems. Many of these equipment and calculation errors can be minimized through a program of periodic checks.

A quality assurance document needs to contain clinically relevant recommendations about acceptable uncertainties in dosimetric procedures and mechanical alignment of treatment equipment. A large number of parameters, all having some inaccuracy, contribute to the overall uncertainty in the three-dimensional dose distribution delivered to a patient. It is recommended that random uncertainties be determined as usual by statistical methods. And be represented by standard deviations. All other uncertainties are to be estimated in some manner, generally as a simple “guesstimate”, so as to correspond roughly to one standard deviation by assuming that the distribution of uncertainties follows a normal distribution. These nonrandom uncertainties are to be combined in quadrature with the random uncertainties to obtain a combined uncertainty characterized by a number that can be considered to be roughly like a standard deviation. Finally the combined uncertainty can be multiplied by some factor, say 2 or 3, to get an overall
uncertainty, which can be looked upon as very l approximately a 95% or 99% confidence interval, respectively.

- The evaluation of accuracy and precision of determination of absorbed dose is a very important component of any physical quality assurance program. Commonly employed dosimeters do not measure dose or exposure directly and the accuracy of l given dosimetric system is subject to change without obvious indication. Accessory equipment (e.g., isodose plotters) also can contribute significant errors; therefore this equipment should receive equal scrutiny. There are many steps in the process of estimating dose in a patient. Each step may introduce errors; therefore careful control of all factors is justified. Variation in biological response between patients and uncertainties of optimal therapeutic dose do not justify dosimetric expediency, due to potential compounding of error. Uncertainties in theoretical conversion constant are on the order of 3%. The incorporation of refinements in these factors (or reduction of other types of systematic errors) in patient dosimetry requires consideration of the clinical experience obtained with less accurate data. The effect on the delivered target dose or dose distribution must be clearly understood before changes are implemented.

It is possible that a significant error can escape detection under the best of circumstances. For this reason, it is highly recommended that all facilities subscribe to some form of out-of-the-way check of their dose delivery capability. Dosimetric comparisons between institutions are useful for this purpose. Some examples of such services follow. The AAPM Radiological Physics Center provides on-site visits and mailed thermo luminescent dosimeter (TLD) comparisons for institutions engaged in certain treatment protocols.
Chapter Three

Material and Method

3.1. Materials:

1. Cobalt-60 machine:

The data was collected from megavoltage machines (cobalt-60). Cobalt-60 unit is known as THERATRON ELITE 100. They are teletherapy units, classified as class 1, type B. The sources are quantity of metallic radioisotope, cobalt-60, sealed inside 2 cm long. typically, the sources are about 2.0 cm in diameter. The sources capsule assemblies are mounted in the source drawer in a cavity approximately 2.8 cm in diameter by 12 cm long, held in place with an end plug and securing clip. The cobalt-60 atoms continuously and spontaneously "decay" to become nickel-60 atoms while emitting gamma radiation. This process has a "half life" of 5.26 years. For Elite 100, the maximum allowable source activity is 15,000 Ci and EQUINOX is 20,000 Ci. The maximum absorbed dose rate in air for the maximum cross section of the radiation beam at 1 meter from the radiation source is approximately 250 cGy/min.

3.2. Study Variables:

The data variables include patient diagnosis, sex, treatment region, patient positioning either supine or prone, positioning and immobilization devices used, area of treatment movement during treatment and patient movement during treatment.

3.3 Study Duration:

This study conducted in period between June 2014 to January 2015.
3.4 **Study Place:**

This study was carried out in Radiation Isotope Center of Khartoum

3.5 **Method of data analysis:**

The data analyzed with excel program to assess the Patient Position Errors using 3D laser pointers

3.6 **Methods of data collection:**

The data variables were included patient diagnosis, sex, treatment region, patient positioning either supine or prone, positioning and immobilization devices used, area of treatment movement during treatment and patient movement during treatment. It was executed by direct check of patient positioning and immobilization devices used during treatment. A patient positioning system has been constructed using laser positions of the markers which allow the smooth translations from standing position horizontal position by means of reclining a treatment table. A conventional different body immobilization device has been used as support for the patient in supine or prone position. The same immobilization devices were used for both traditional laser centering procedures and initial reference position acquired during the simulation procedure and/or the first irradiation session. The same patient was asked to perform the alignment procedure at five separate sessions during treatment course. The reclining as well as conventional set-up procedure was performed consecutively. These procedures were performed at 10 fractions during 10 days, thus corresponding to long term course radiotherapy. The immobilization devices were positioned on the indexed treatment table and the table was then titled for the reclining positioning technique. Using the reclining technique, the patient was asked to remain the same position. Professional radiotherapy technicians were asked to reposition twenty patients
carefully using traditional laser centering procedures. For traditional set-up procedure, the same patient was asked to climb onto the couch with immobilization devices already place. After each of set-set procedures, the position is recorded using laser positioning system. The laser positioning system thereby generates a displacement vector in the x-, y- and z direction. The regions of interest used include the surface from lower pelvis and up to the head.

3.7 Ethical Issues:

- No patients’ data were published

- Permission from Radiotherapy department
Chapter Four

The Results

Table 4-1 show the age distribution for both gender among the study sample

<table>
<thead>
<tr>
<th>Age Group (years)</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-29</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>30-34</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>35-39</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>40-49</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>50-54</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

This study describes the technology and methods involved in a system for automatically checking the position of patients at radiotherapy units. The patient Alignment and position monitoring is carried out by comparing the current laser Positions of the markers with those of an initial reference position acquired during the simulation procedure and/or the first irradiation session. The following tables and graphs show summary of the results including displacement of
conventional Set-up (mm) and laser set-up (mm). The set-up procedure using conventional set-up laser positioning system results in an increased accuracy of actual treatment position.

Table 4-2 shows the x, y, z mean and standard deviation displacement readings compared with reference point

<table>
<thead>
<tr>
<th>axis</th>
<th>Mean±SD displacement</th>
<th>Reference point</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>4.00±0.46</td>
<td>3.5</td>
</tr>
<tr>
<td>y</td>
<td>3.73±0.18</td>
<td>3.75</td>
</tr>
<tr>
<td>z</td>
<td>3.87±0.36</td>
<td>3.5</td>
</tr>
</tbody>
</table>
The figure 4.1: shows position displacement in x-axis vs. number of cases

Figure 4.2: correlation between displacement and measured value in x axis
The figure 4.3: shows the displacement in y axis vs. number of cases

Figure 4.4: correlation between position displacement and measured value in y axis

\[ y = -0.455x + 1.829 \]
\[ R^2 = 0.412 \]
Figure 4.5: the shows displacement in z axis vs. number of cases

Figure 4.6: correlation between position displacement and measured value in z axis

Chapter Five
5.1 Discussion:

This is an experimental study designed to evaluate patient treatment verification within external beam radiotherapy using laser monitor. The study involved 50 patients undergoing radiotherapy treatment at Radiation and Isotopes Center of Khartoum. For the group of patients where age distribution was measured, 24% of patients were within the 25-29 years age range, 12% of patients were within the 30-39 years age range, 16% of patients were within the 36-45 years age range, 28% of patients were within the 40-49 years age range, 20% of patients were within the 50-54 years age range. The key parameters for this group are shown in Table 4.1. The main objective of this study is to assess the position error due to random and systematic error using laser monitor. This study involved 50 patients undergoing radiotherapy treatment position errors resulting from systematic and random errors using laser, the mean ± SD of the displacement in x, y, and z were calculated. The results of these study showed that the x axis displacement is more than the other axis due to rotational movement (pronation and supination) beside change in the swelling, breathing or tumor size may cause change in the position of the skin marks (Conventional Set-up is equally (4.87±0.47 mm) for x-direction reading), (4.00±0.46 mm) y, and Laser Reading (3.5 ± 0 mm). (Conventional set-up (4.38± 0.19 mm) for y, (3.73±0.18 mm) y direction, and Laser is (3.75 ± 0). conventional set-up is (4.83± 0.34 mm) for z-axis, (3.87 ± 0.36 mm) z direction and Laser is (3.5 ±0mm). In addition, the use of the laser beam for automatic position control is envisaged.
5.2 Conclusion:

This study was attempted to show the evaluation for geometric treatment verification within external beam radiotherapy using laser monitor. There are important considerations for accurate patient set-up such as laser, CT simulators, and individual immobilization tools. After patients were aligned using skin marks, result taken before and after using laser and there is shift been noticed, random errors reflect the errors primarily caused by motion of the patient within the immobilizer, whereas systematic errors are more likely to be caused by errors in interpretation of the desired position, the actual day-to-day variation noted, most of the observed shift in table (4-2), The results revealed significant repositioning errors even in highly controlled conditions. Affecting particularly body areas relatively far from the skin reference points used for laser alignment.

5.3 Recommendations:

- Reduction of organs motion is possible, applying movements reducing and gated treatment and adjusting the some physiology activities to treatment timing.

- Proper immobilization technique and staff experience can substantially affect to reduce this error.

- Errors and Standard deviation must be calculated and correction must have place
5.4. References:


Ivan A. Brezovicha and Stephen Jordan, A device for precision positioning and alignment of room lasers to diminish their contribution to patient setup errors, Received 23 October 2006; accepted 25 June 2007.


Appendix