Measurement and calculated dose in breast phantom

Dissertation submitted in fulfillment for the
Degree of Bachelor of Health Science in Medical Radiation

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CERTIFICATE

This is to certify that the dissertation entitled

" Measurement and calculated dose in breast phantom"

is the bonafide record of research work done by

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During the period from October 2003 to April 2004 under my supervision.

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1. ABSTRACT

The aim of this study was to compare the dose calculated by NUCLETRON PLATO treatment planning computer with thermoluminescence dosimeter (TLD) measurement in breast cancer radiotherapy. The absorbed dose distribution for one-field technique and two-field techniques were discussed. The study was done by comparing interest point dose values calculated by treatment planning computer with dose values measured by LiF TLDs. Utilizing an anthropomorphic phantom, TLDs were placed inside a breast phantom and were irradiated with 6MV SIEMENS MEVATRON linear accelerator. One-field technique and two-field techniques were used for the irradiation. Readings from irradiated TLDs were analyzed. Absorbed dose distributions for one-field and two-field techniques were obtained from the computer. Based on the results, dose values for the four points of interest in which calculated by the treatment planning computer and measured by TLDs were within 13%. Inexact location of points of measurement during phantom's set up caused large deviation between the calculation and TLD measurement. TLD measurement and the calculation do not comply to ICRU recommendation.

2. INTRODUCTION

Breast cancers are very common in women. In recent years, the trend of breast cancer management has been toward breast conservation, with the surgical intervention limited to lumpectomy, usually followed by radiation therapy [16]. External radiation therapy refers to the therapeutic application of ionizing radiation from an external beam. The purpose of cancer therapy is to destroy malignant cells while leaving the rest of the body intact, or at least able to recover and capable of eliminating the destroyed cells. Its beneficial effects are not sudden or dramatic but slow and progressive, taking some time before a patient is aware of the improvement.

Before a patient undergoes radiation therapy, the treatment has to be planned. Treatment planning is the process of determining the best method of treating a tumor with radiation. The major objective of treatment planning is to deliver a uniform radiation dose to the tumor while healthy tissue and critical structures are protected [8]. Area outside the target volume should receive as little radiation as possible. Therefore, a plan that treats the tumor volume was developed to give as homogenous a dose distribution as possible throughout the clinical target volume. A slightly increased dose may result in unacceptable damage to normal tissue while a dose which is too low may make the treatment less effective.

Treatment planning provides a permanent record of dose calculations and distributions so that others may, in the future, understand the treatment plan. The

permanent record is also includes the prescription, diagrams of the treatment field, tattoo identification, simulation and radiograph, as well as other computations performed before, during, and even after each course of treatment.

In breast treatment planning, the accurate delineation of the target volume is very important because of the non-uniform shape of each breast and the close proximity to the underlying lung [4]. The standard treatment technique for breast tumors consists of two tangential fields covering the target. The only critical tissue involved is the fraction of the lung close to the breast that is within the field. The treatment objective is typically only the dose to the target [8]. Treatment planning of the intact breast has generally performed using two-dimensional (2D) techniques. In 2D treatment planning, all dose distributions are calculated on the central-axis plane [19].

In order to understand where energy from x-rays is absorbed and in what amounts, materials which absorb radiation as human tissue are used. Therefore, RANDO® anthropomorphic phantom was used to study the distribution of dose. The RANDO® phantom was developed in an effort to overcome the disadvantages of non-uniformity of materials, size and shape. The RANDO® phantom contains a natural human skeleton of appropriate size, adjusted within a mold to normal relationships with body contours.

The soft tissues are molded of an extremely tough plastic based on isocyanate rubber. The phantom material is processed chemically and physically to achieve a density of 0.985 g/cm^3 and an effective atomic number of 7.30 which these values are based on the International Commission on Radiation Protection

(ICRP) and Measurement Standard Man, represent a composite of muscles, nominal body fats, fluids and etc. From Table A.1 (refer to Appendices), the differences in density and effective atomic number between water and RANDO® phantom were not much. Therefore, the phantom would absorb radiation in a manner identical to the human phantom. Thus, the material is sensibly tissue-equivalent over the entire range of therapeutic energies in common use today.

Thermoluminescence dosimetry (TLD) has proved a useful technique for a variety of purposes in radiotherapy including measurements of therapy machine output, beam uniformity checks, and the measurement of absorbed dose in phantoms and *in vivo* for both internally and externally applied fields [18]. The advantages of TLDs make them very useful for measurements in anthropomorphic phantom [14]. In addition, it can be used for *in vivo* dose measurements in anthropomorphic phantom.

Theoretically, themoluminescence is a process in which materials emit light when they are heated. This process involves two steps. In the first step, the solid is exposed to the exciting radiation, such as particle or electromagnetic radiation at a fixed temperature. In the second step, the excitation is interrupted and the sample is heated [15]. The TLD phosphor that is used in TLD is lithium fluoride (LiF). Trace quantities of magnesium or titanium are also added in TLD. LiF have an effective number 8.18 which is close to that of tissue and hence absorbs ionizing radiation in a similar manner.

TLD consist conduction band, forbidden zone and valence band. In forbidden zone, there are many traps which located in different states as shown in Figure

A.2 (refer to Appendices). Theoretically, when the TLD is irradiated, electrons in the valence band are raised to the conduction band of the crystal. The energy for this transfer is supplied by the ionizing radiation. These electrons may fall back into traps where they are held. The electrons remain in that condition until the crystal is heated between 200°C to 300°C. As a result, the trapped electrons acquire enough energy to escape back into conduction band. From conduction band, the electrons immediately drop back to the valence band. In the process of dropping back, light photons are formed. The traps occur at different levels in forbidden zone. Light is emitted over range of temperature. The intensity of emitted light is measured and recorded by using photomultiplier, amplifier and recorder. The intensity of light output is proportional to accumulate dose after it is heated to high temperature.

Both SIEMENS MEVASIM simulator and SIEMENS MEVATRON linear accelerator produced x-rays. The basic principle for both equipments is similar to that of the x-ray tube, i.e. electrons are accelerated, they bombarded a target and x-rays are produced [2]. The method employed for accelerating electrons in a SIEMENS MEVATRON linear accelerator, however, is very different compare to SIEMENS MEVASIM simulator. In a linear accelerator, the accelerating force is provided by electromagnetic waves [2]. Linear accelerator produced x-rays at higher energies compare to simulator.

This study focuses on comparison of the dose calculated by NUCLETRON PLATO treatment planning computer with thermoluminescence dosimeter (TLD)

measurement. In addition to this, the absorbed dose and isodose distribution in one-field and two-field techniques are discussed.

3. REVIEW OF LITERATURE

The introduction of computer technology in radiotherapy planning should therefore not be regarded as implying manual procedures are obsolete [22]. The use of computers will introduce new risks of error because of both hardware failures and software mistakes. Although hardware failure leading to errors in calculation are unusual, their importance is too often underestimated [22]. Software mistakes are more frequent. Therefore, initial and systematic checks should be performed to detect and correct them.

According to World Health Organization (WHO), an effective way of checking the quality of the entire dosimetric procedure, from the performance of the treatment machine to the accurate positioning of the patient, is to make absorbed dose measurements on the patient and when possible, in body cavities [22]. *In vivo* dose measurements are very important in determining the actual dose to the target volume as well as unwanted dose around the tumour of patients undergoing radiotherapy.

Saw et.al (2000) reported that computing doses using data measured in a phantom has been the standard of practice in radiotherapy because direct measurement of doses in a patient is usually not possible [20]. Such measurements can reveal technical errors in the treatment dose. Therefore, the introduction of computer technology should help to improve both the quality of the treatment plan and the dosimetric accuracy of the treatment.

Kowalski and Smith (1998) stated that treatment planning system can estimate dose to only some parts of the breast [11]. In their studies, range of dose throughout the entire breast from mantle field radiation was determined by making measurements with TLDs in an anthropomorphic phantom. Based on their results, the computer plans agreed in the trends of the dose distribution in the different regions as measured by the TLDs [11]. Hence, TLD is useful as *in vivo* dosimetry in order to verify treatment planning system. Herrick et.al (1999) reported that the usual approach described in the literature for testing treatment planning software is to compare treatment planning calculated dose values with dose values measured in a phantom using a variety of clinically relevant set up situations[9].

Lederer et.al (1997) mentioned that the simulation of breast fields using an isocentric set up technique involved the placement of the isocentre, the determination of the gantry angles and the selection of the lung shields [13]. Simulator is the most important device during simulation. A simulator is an apparatus which uses a diagnostic x-ray tube but duplicates a radiation treatment unit in terms of its geometrical, mechanical and optical properties [10].

SIEMENS MEVASIM simulator is similar to that of a conventional diagnostic x-ray unit mounted in a manner that allows the x-ray beam to mimic the high energy beam from a treatment unit. However, there are some differences between simulator and linear accelerator. Simulator has image intensifier and works with low voltage (in kVp). While linear accelerator has no image intensifier and the voltage unit is in megavoltage. It is capable to deliver voltages over the

range of 40 to 150 kVp and tube currents between 50 and 600 mA [2]. Exposure times as short as a few milliseconds and as long as several seconds are required [8]. The main function of a simulator is to display the treatment fields so that the target volume may be encompassed without delivering excessive irradiation to surrounding normal tissues [10].

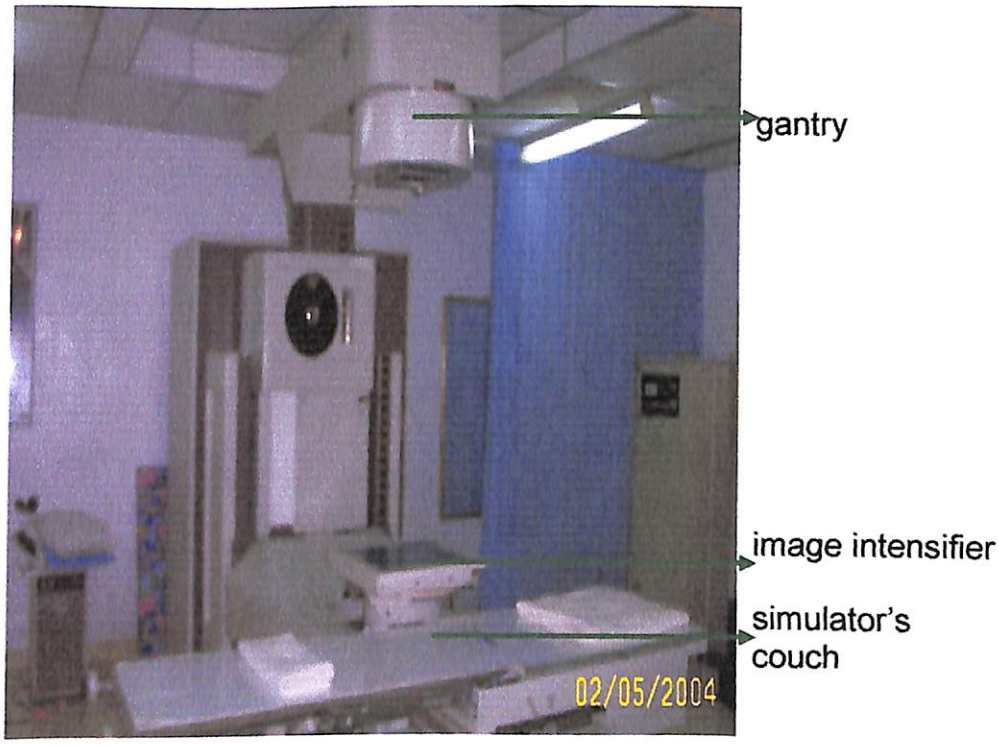


Figure 3.1. SIEMENS MEVASIM simulator. Important device during simulation and verification.

There are four major components of the simulator, namely; gantry, image intensifier, couch and local and remote control panel. The gantry supports the x-ray tube and collimator assembly at one end and the image intensifier

mechanism at the opposite end. It is mounted on a stable stand that allows the gantry to rotate completely 360 degrees around the isocenter. Isocentric accuracy should be less than 0.75 mm. Most simulators are equipped with an image intensifier, so that the patient's anatomy can be visualized under fluoroscopy before radiographs are taken [8]. The cassette holder is attached to the top of the intensifier. It can be rotated for access. It will accommodate different cassette sizes from 35 x 35 cm to 35 x 43 cm.

The simulator's couch should be identical to that treatment machine (linear accelerator) to permit accurate reproducibility of set up. The couch has longitudinal, lateral and vertical motion. All the simulator movements must be accessible from a remote console in the operator control area as well as from a hand pendant or couch control on the simulator. Facilities for control of the roomlights, field lights, optical distance indicator and lasers are also required on local and remote control panels [8,10].

As mentioned earlier, linear accelerator is a device which uses high frequency electromagnetic waves to accelerate charged particles such as electrons to high energies through a linear tube. Khan (1984) stated that the high energy electron beam itself can be used for treating superficial tumors or it can be made to strike a target to produce x-rays for treating deep seated tumors [10].

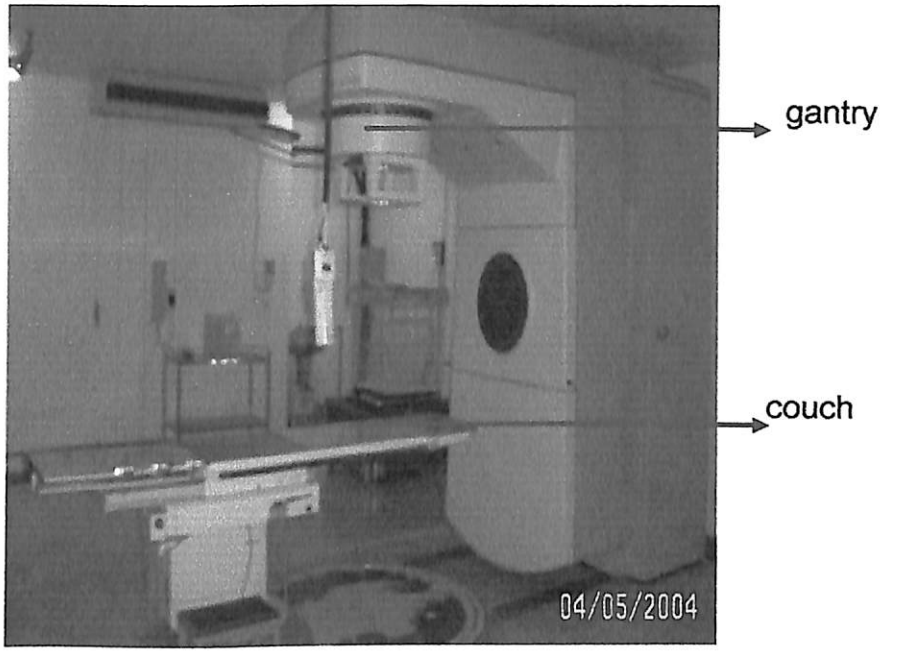


Figure 3.2. SIEMENS MEVATRON linear accelerator. Radiation source in this study. Noticed that there is no image intensifier for linear accelerator.

4. OBJECTIVES OF THE STUDY

4.1 Comparison of the dose calculated by NUCLETRON PLATO treatment planning computer with thermoluminescence dosimeter (TLD) measurement.

4.2 Comparison of the absorbed dose distribution for one-field and two-field techniques.

5. MATERIALS AND METHODS

5.1 Phantom's set up

The measurements were done in an anthropomorphic phantom (Alderson RANDO® phantom). The phantom was placed in a supine position on the simulator's couch. The head of the phantom was supported by a folded bedsheet as shown in Figure 5.11.

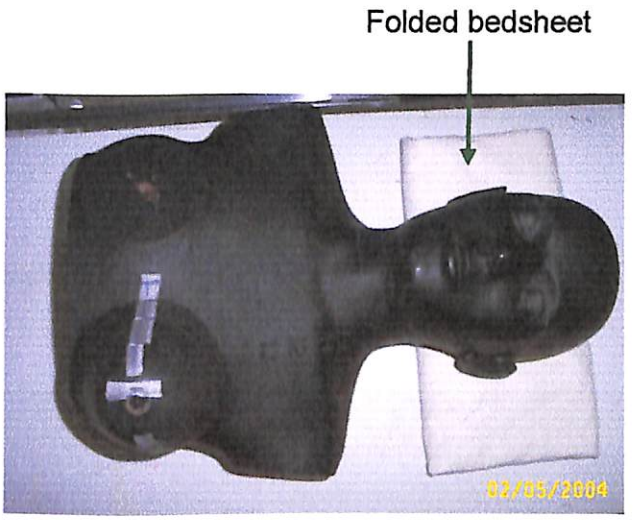
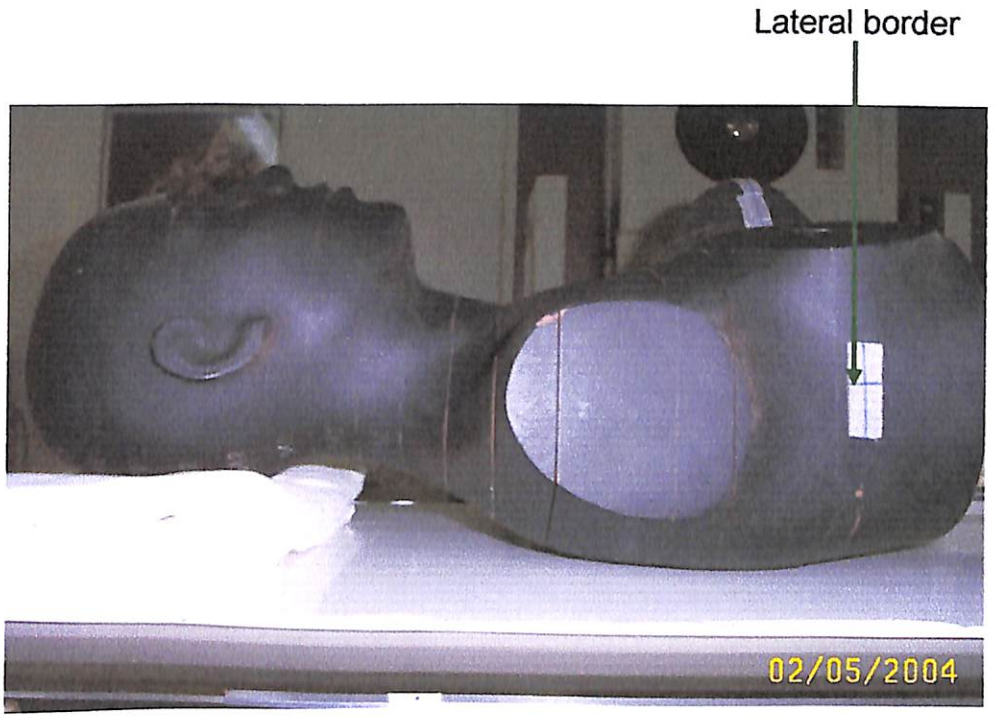


Figure 5.11. The RANDO® anthropomorphic phantom in supine position on the couch.

The phantom was aligned using sagittal and horizontal lasers. The medial and lateral borders were marked as shown in Figure 5.12 and Figure 5.13. Then, the outline or body contour was drawn on a graph paper.

(a)



(b)

Figure 5.12. Lateral border. Noticed that picture (a) is lateral border for the left side and picture (b) is lateral border for the right side.

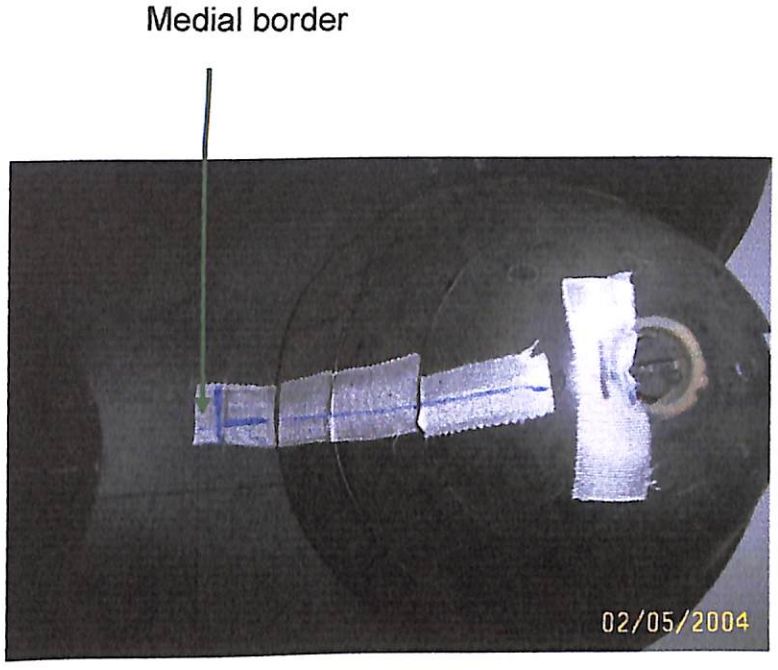


Figure 5.13. Medial border. The green arrow showed the medial border that was marked on phantom.

During this procedure, thermoplastic was used to obtain body contour. Since the thermoplastic may not retain the contour dimension when transferring it from phantom to the graph paper, the calliper was used to measure anteroposterior and lateral diameters. From the measurement, the anteroposterior diameter is 28.0 cm while the lateral diameter is 18.0 cm.

The medial and lateral borders were marked in the graph paper as shown in Figure A.3 (refer to Appendices). The top of the left breast phantom was opened to verify the TLDs position. The positions were marked as M and L as shown in Figure 5.15. M and L were the points for TLD measurement and calculated dose by NUCLETRON PLATO treatment planning computer. The points of

measurement were marked on the graph paper. The points were determined using the side lasers and by adjusting the couch.

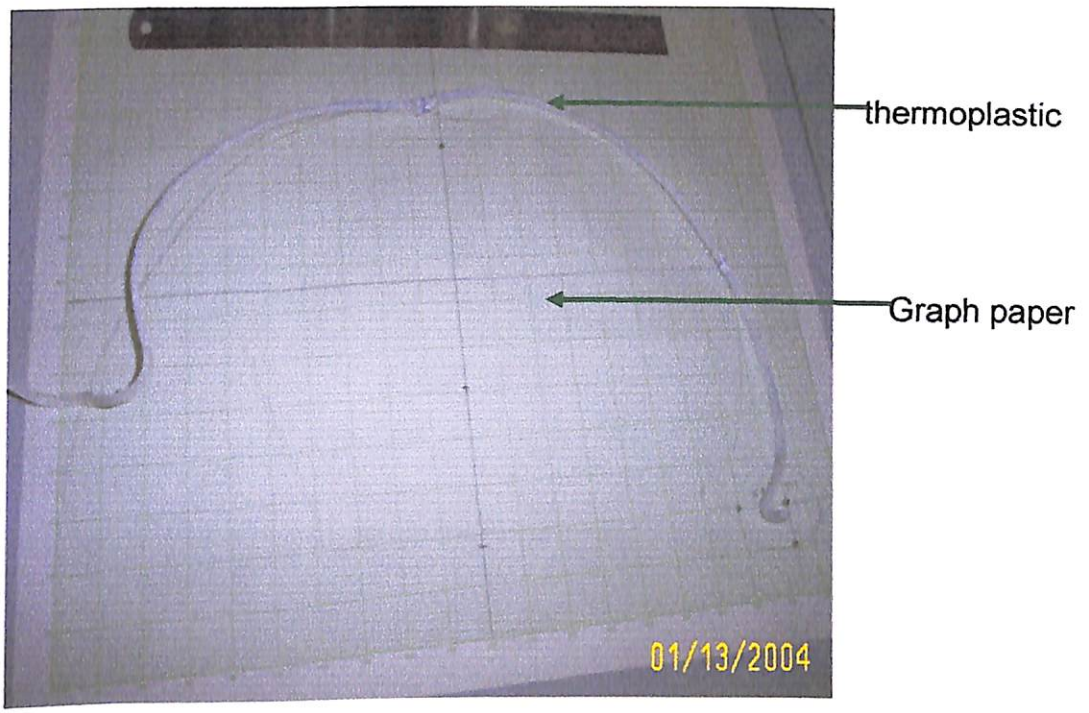
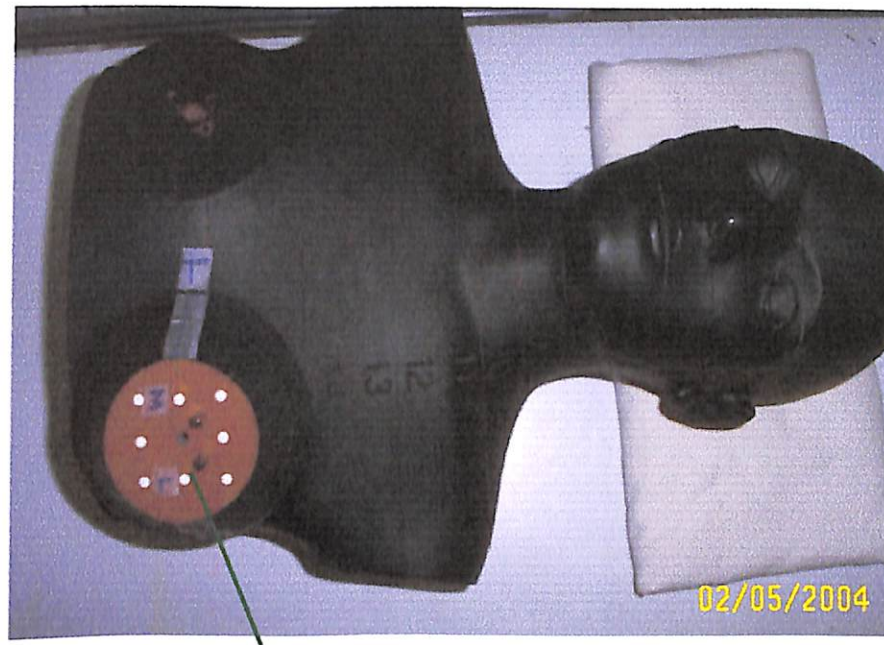


Figure 5.14. The instruments that were used to draw body contour.

(a)



(b)

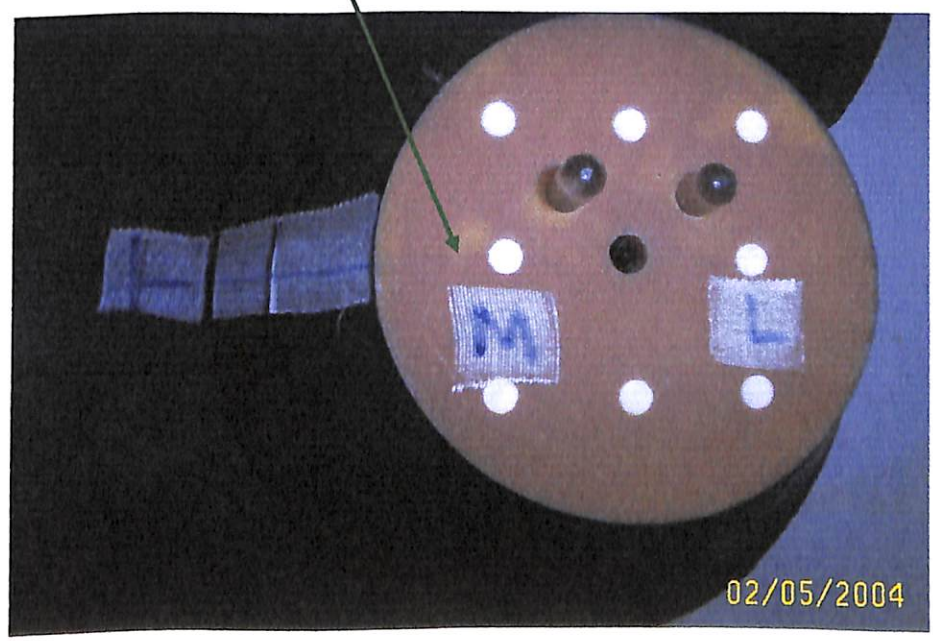


Figure 5.15. The top view of left breast phantom was opened to verify TLDs location. The position of TLDs were marked as M and L which is shown in (b).

5.2 Planning measurements using NUCLETRON PLATO treatment planning computer

Figure 5.21. NUCLETRON PLATO treatment planning computer.

Figure 5.22. Digitizer. This device was used to digitize the phantom contour for direct input to the treatment planning computer.

NUCLETRON PLATO treatment planning system consist direct digitizer entry from paper tracing or contour of body outline. The transverse contour of RANDO® anthropomorphic phantom was digitized to the NUCLETRON PLATO treatment planning computer. The phantom's contour was read by a sensing device to digitize the contour for direct input to the NUCLETRON PLATO.

Several data need to be keyed in NUCLETRON PLATO. The source-to-axis distance (SAD) technique was used for measurement. A pin (medial border) is a reference point on the skin surface that is related to the position of the isocenter. More commonly, however, a pin was set for an isocentric treatment and was particularly useful when the field center was located in an anatomically variable location such as breast tissue.

For two-field measurement, the beam's position were medial tangential and lateral tangential. According to the contour, the field size for the phantom was 13 x 10 cm. The gantry was rotated to 299° and 126°. The dose was prescribed to 200 cGy. From treatment planning computer, monitor unit (MU) to be used for both fields were determined. MU was set to 103.2 MU for medial tangential field while MU for lateral tangential field was set to 106.6 MU. 6MV photon beam was used for the measurements. The isodose level was adjusted to 100.0%. Isodose distribution and absorbed dose distribution were developed from NUCLETRON PLATO.

While for one-field measurement, the dose was prescribed at 200 cGy and the beam was angled to 299° with 13 cm x 10 cm field size. The energy was set

at 6 MV photon beam with 206.5 MU. The isodose and absorbed dose distributions were developed for one-field technique.

5.3 Irradiation using 6MV SIEMENS MEVATRON linear accelerator

A SIEMENS MEVATRON linear accelerator providing 6MV photon beam was the radiation source used in this study. The phantom was set up similar to its position during simulation. According to the treatment plan, the table should be raised from 100 cm to 101.88 cm and shifted 9.0 cm to the left as shown in Figure 5.31. The gantry was rotated to 299° and 126°.

The LiF TLD chips of approximately 3.1 mm x 3.1 mm x 0.89 mm were used for dose measurements. The TLDs were calibrated at the Malaysian Institute of Nuclear Technology Research (MINT). The LiF TLDs were inserted in small holes which are labeled as M and L (see figure 5.15(b)). For two-field technique, the phantom was irradiated with 103.2 MU for left medial tangential (299°) and 106.6 MU for left lateral tangential (126°) at 100 cm SAD, 13 cm x 10 cm field size and 6 MV energy. After that, the measurements were taken by placing the other LiF TLD chips at the same position with gantry position at 299°. The monitor unit was set at 103.2 MU with 6 MV and 13 cm x 10 cm field size. The LiF TLDs were irradiated and labeled. Other LiF TLDs which were inserted with the same position were used. The LiF TLDs were irradiated at beam angle of 126° with 106.6 MU. The field size was set at 13 cm x 10 cm with 6 MV energy. After irradiation, the LiF TLDs were labeled.

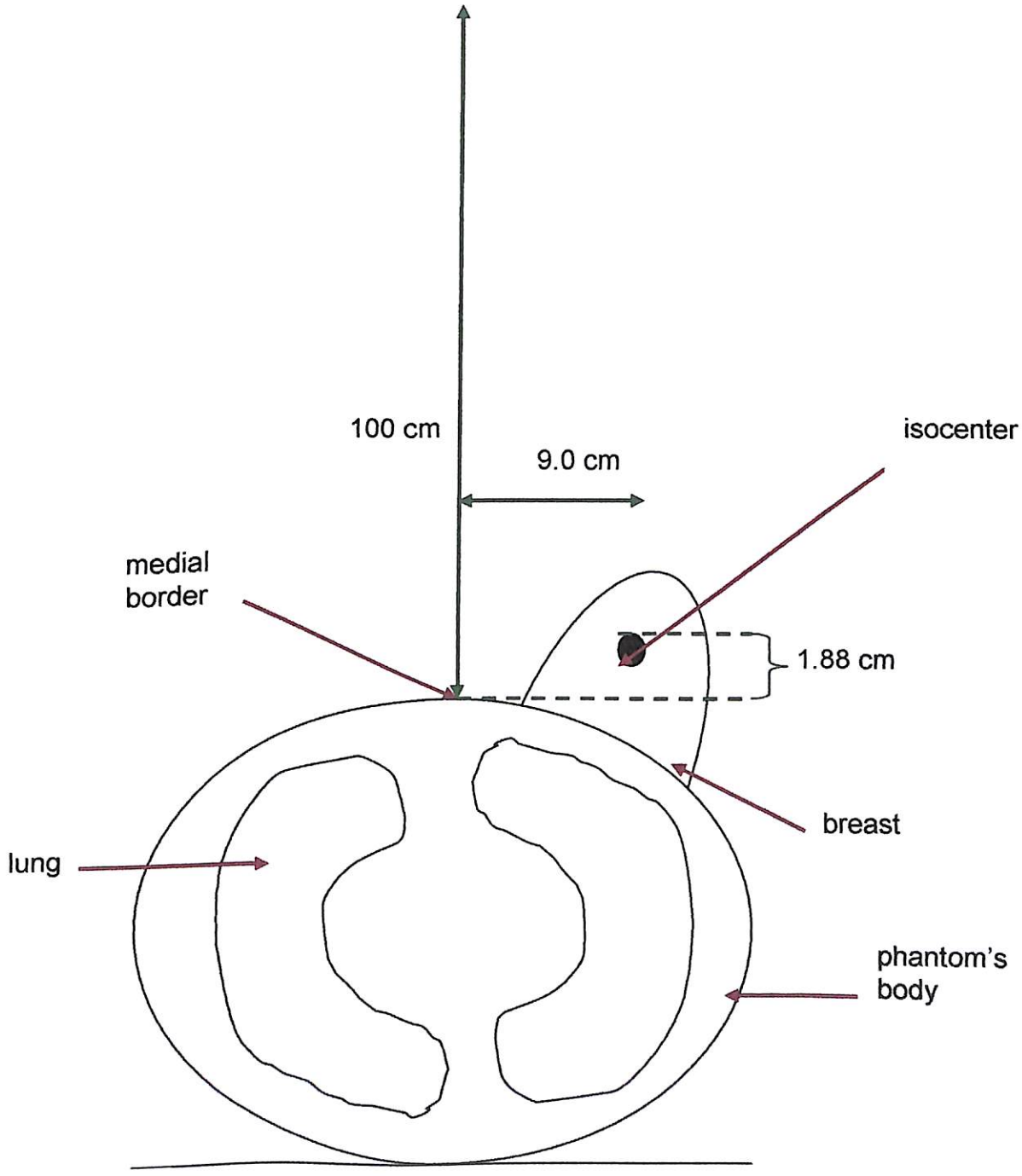


Figure 5.31. Isocentric set-up. The table was raised from 100 cm to 101.88 cm. The center was 'shifted' 9.0cm laterally, and a new axis was established.

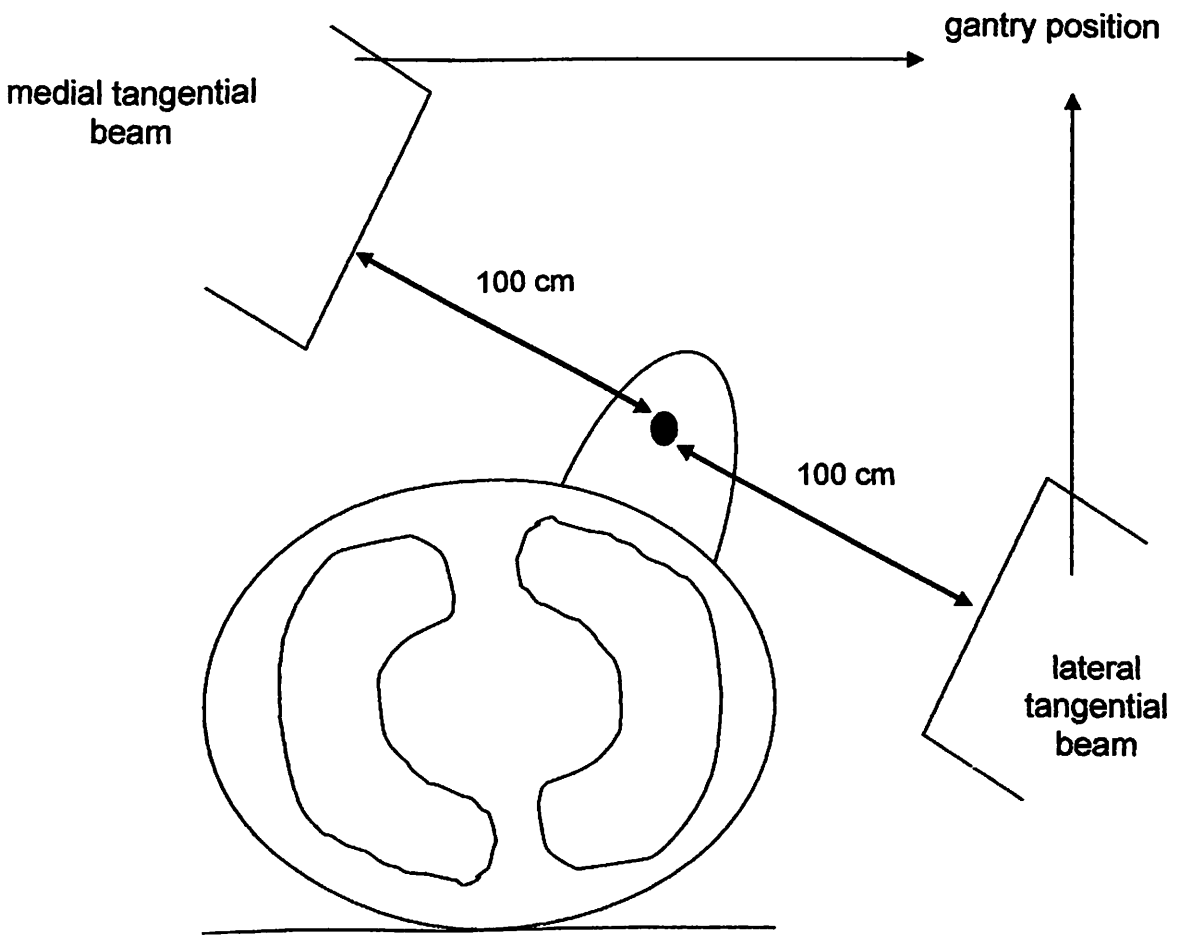


Figure 5.32. Gantry rotation for two-field technique. The gantry was rotated to medial tangential and lateral tangential.

In one-field technique, the beam was angled at 299°. The LiF TLDs were irradiated with 6 MV energy and 206.5 MU. The field size was set at 13 cm x 10 cm with 100 cm SAD. Irradiated LiF TLDs were labeled. A Harshaw model 200D/2080 was used as the TLD reader. The exposed LiF TLDs were read out with a 50°C preheat temperature and a reading temperature of 50–300°C at the acquire rate of 10°C per second without any annealing inside the reader [15]. A filtered N_2 gas free from O_2 and water vapor was flown through the heating planchet during reader operation to avoid any spurious thermoluminescence[1].

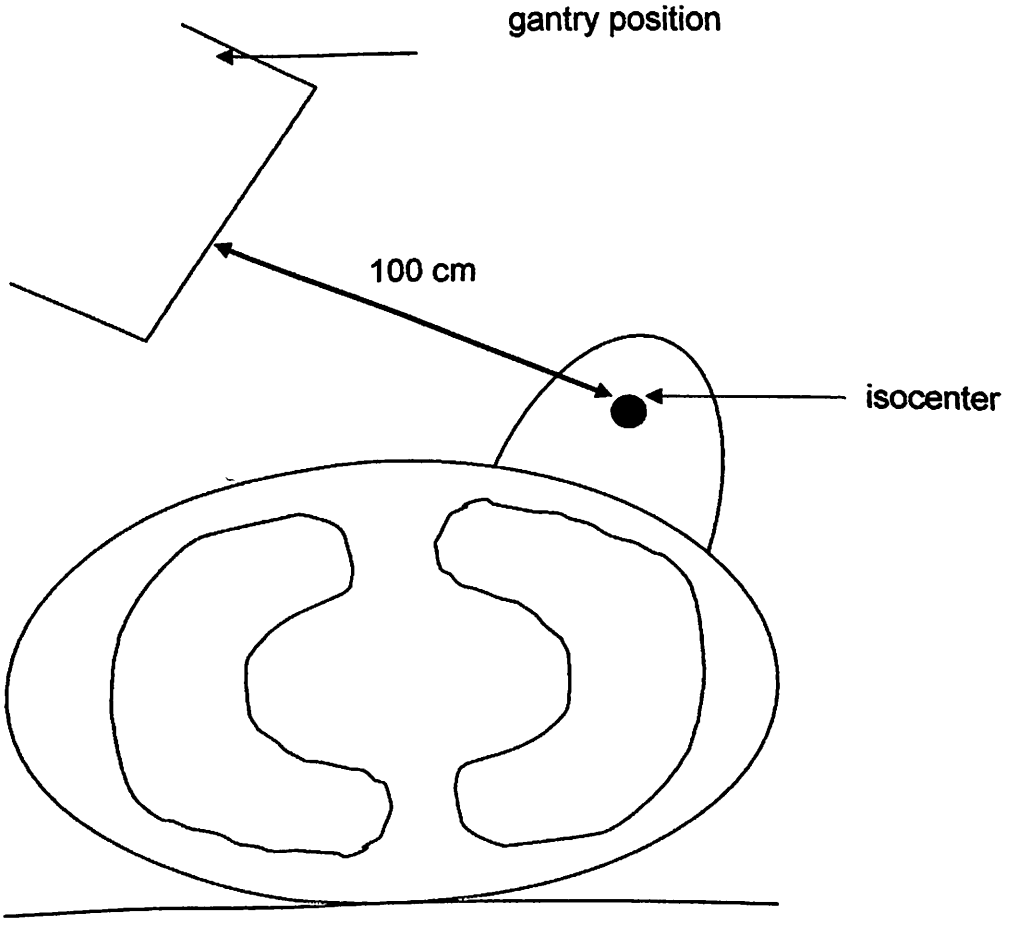


Figure 5.33. Gantry rotation for one-field technique. The gantry was rotated to 299°.

6. RESULTS

Table 6.1. Comparison of the dose calculated by NUCLETRON PLATO treatment planning computer and LiF TLD measurement.

Technique	TLD (cGy)		Treatment planning computer (cGy)		%Deviation	
	M	L	M	L	M	L
One field (medial tangential)	201.990	171.385	226.600	197.300	10.9	13.1
Two field	176.952	186.537	199.400	206.500	11.3	10.0
(i) medial tangential	97.699	81.116	-	-	-	-
(ii) lateral tangential	75.227	100.307	-	-	-	-

The results of calculated and measured doses are shown that the discrepancy between the two calculation method were within 13%.