Study of Dosimetry in various cases in Radiotherapy

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Dedicated

to

My Family

DECLARATION

I hereby declare that the material presented in this thesis is the result of the original investigations carried out by me under the supervision of **Prof. B.R.S Babu.** This thesis has not been submitted for the award of any degree, diploma, Associateship, fellowship etc. of any other university or institute.

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CERTIFICATE

This is to certify that the thesis entitled '**Study of dosimetry in various cases in Radiotherapy**' by **Ms. Sushama.P** submitted to the University of Calicut, for the award of the degree of Doctor of Philosophy under the Faculty of Science is based on the results of the investigations carried out by her under my supervision and guidance. This thesis has not been submitted for the award of any degree, diploma, associateship, fellowship etc of any other University or institute.

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INTRODUCTION

GENERAL INTRODUCTION

Radiotherapy is one of the most important methods to treat cancer disease. Radiotherapy can be given alone to the tumour or together with other methods like surgery and chemotherapy. Meticulous planning and careful implementation of the treatment is highly essential to get good results of radiotherapy. Dosimetry studies help to find out whether the dose prescribed which is essential for destroying the tumour, is received by the tumour cells. In addition such studies help to deliver the dose to the exact position without giving much dose to the surrounding normal cells.

Radiotherapy mainly has two parts viz., - external radiotherapy and brachytherapy. In external beam therapy the tumour is at a particular distance from the source of radiation. Here the radiation passes through different media before reaching the tumour. In the patient, the radiation passes through skin and other normal tissues along its path before reaching the tumour which is usually at a depth inside the patient. This causes attenuation of radiation.

Low energy megavoltage beams like cobalt -60 gamma rays, 4 to 6 MV accelerator generated X-rays are usually used for relatively shallow or moderately deep tumours such as, head and neck tumour, breast tumours and tumours in extremities. Beams are directed towards the tumour in different ways. Single beam and multiple beams are used for the treatment depending on the site and depth of the tumours. Multiple beams are usually given to deep seated tumours like carcinoma cervix, carcinoma esophagus and carcinoma stomach. This helps to reduce dose to normal cells through which the radiation passes before reaching the tumour. In the case of multiple beams, parallel beam technique is the most commonly used in external radiotherapy. For parallel opposite beams, the body thickness should not exceed 17cm. This limit on the distance is decided by the ratio of maximum peripheral dose to midline dose[1].

X-ray beams in the energy range of 10 to 25MV allow optimal treatment techniques for deep seated tumours like in thorax, abdomen and pelvis. Here the tumour gets more dose while sparing the skin and other normal tissues. Here also as in the case of low energy beam the ratio of maximum peripheral dose to mid line dose is an important factor to be considered. Superficial tumour at a depth of about 5cm can be treated by electron beams. Electron beam energy in the range of 6 to 20 MeV is usually used for this therapy. These beams are often used in conjunction with X-ray beams either as a boost or a mixed beam treatment. The depth dose distribution of electron beam is in such a way that it can be treated for superficial tumour without giving much dose to normal tissues beyond the tumour. It is used for skin, lip and chest wall irradiation.

Brachytherapy

Brachytherapy is another method of radiotherapy. Some tumours are best treated by brachytherapy alone or in conjunction with external beam. It can be used in cases like carcinoma cervix, endometrium, esophagus, oral cancers and breast cancers[2]. In brachytherapy the source is near to the tumour. The radiation is attenuated very fast as it goes away from the source in to the tissue. Therefore the tumour gets more dose while surrounding tissues get very little dose in the case of brachytherapy. The present study concerns the cancer treatment by an external beam therapy.

New techniques

In conventional radiotherapy, cobalt therapy machines and linear accelerators are used for the treatment of tumors. But new techniques such as Intensity Modulated Radiotherapy (IMRT)[3], Conformal Radiotherapy[4], Image Guided Radiotherapy(IGRT)[5] and Tomotherapy[6] have opened a wide range of treatment methods in external Radiotherapy. Although all diagnostic imaging equipment have some role in defining and localizing target volume to be treated, the new imaging equipments like Computed Tomography (CT)[7], Magnetic Resonance Imaging (MRI)[8], Conventional Simulators[9], Computed tomography simulators[10] and Positron Emission Tomography (PET)[11] have important roles in the development of radiotherapy. There are two dimensional (2D) treatment planning systems and three dimensional (3D) treatment planning systems. Before the treatment of cancer, planning is done in a treatment planning system such as 2D or 3D systems. This is used especially when multiple beams are used for radiation therapy and for electron beam therapy. When images from Computed Tomography (CT), Magnetic Resonance Imaging (MRI) are taken, 3D planning system helps to view the tumour and other near by organs three dimensionally and to achieve a definite plan to give high dose to tumour and relatively negligible dose to the other normal organs. This is the advantage of a 3D planning system. Both 2D and 3D planning systems help to accurately deliver radiation dose to the tumour. However, Economic restrictions, staff requirements, have made these modern techniques, confine only to a few institutions and are therefore beneficial only to a few patients.

The main aim of radiotherapy is to kill all tumour cells while sparing normal cells surrounding the tumour tissue. Careful planning is a process that involves the determination of treatment parameters considered optimal in the management of a patient's disease. These parameters include target volume, dose limiting structures, treatment volume, dose prescription, dose fractionation, dose distribution, positioning of the patient, treatment machine settings and adjuvant therapies.

Target volume includes tumour and its occult spread to the surrounding tissues or lymphocytes. In addition to target volume we also have to consider treatment volume for radiotherapy. The treatment volume should be larger than the target volume to allow for limitations of the treatment techniques. In conventional radiotherapy, the treatment volume is larger than that in the case of special new techniques like Intensity Modulated Radiotherapy (IMRT), radio surgery[12], conformal therapy and other new methods of treatment. In external beam therapy target volume and treatment volume help to set the field size in the therapy machines, before the treatment begins.

Dosimetry

Radiation dosimetry deals with methods for a quantitative determination of energy deposited in a given medium by directly or indirectly ionizing radiations. Dosimetry helps to verify the dose actually delivered to the tumour, skin, different organs and at points of interest. A number of quantities and units have been defined for describing radiation beam. These are particle fluence, energy fluence, particle fluence rate and energy fluence rate. The energy of photons is imparted to matter in a two stage process. In the first stage, the photon transfers energy to the secondary charged particles (electrons) through various interactions such as the photoelectric effect, the Compton effect, pair production and Raleigh's scattering. In the second stage, the charged particles namely the electrons produced as a result of primary interaction, transfer energy to the medium through atomic excitations and ionizations. The average amount of energy transferred indirectly from Ionizing radiations such as electromagnetic radiations to directly ionizing radiations such as secondary electrons without concern as to what happens after this transfer is called Kerma. The kerma is defined as the mean energy (dE) transferred from the electromagnetic radiation to charged particles (electrons) in the medium per unit mass d*m* (dE/dm).The unit of kerma is joule per kilogram (J/kg). kerma has the units of Gray (Gy), where 1 Gy = 1 J/kg.

Cema (Converted energy per unit mass) is another quantity applicable to directly ionizing radiations such as charged particles. The cema C is the quotient of dE_c/dm, where dE_c is the energy lost by the primary charged particles. The unit of cema is Gray (Gy).

Absorbed dose is total energy absorbed by the medium due to both indirectly and directly ionizing radiations. For indirectly ionizing radiations, energy is imparted to matter in a two step process. In the first step (resulting in kerma), the indirectly ionizing radiation transfers energy as kinetic energy to secondary charged particles. In the second step, these charged particles transfer some of their kinetic energy to the medium (resulting in absorbed dose) and lose some of their energy in the form of radiative losses (bremsstrahlung, annihilation in flight). The absorbed dose is defined as the mean energy e imparted by ionizing radiation to matter of mass m.The energy imparted, e, is the difference between the incident energy and the energy lost. The absorbed dose is conventionally expressed in units of Gray (Gy).

A dosimetric evaluation helps to find out the dose received by the patient during treatment, with different treatment techniques and allows optimization of the dose. There are different methods by which dose can be measured. Thermoluminescent dosimeters, different type of detectors and even treatment planning system help to do the dosimetry in radiotherapy.

There are different methods by which dosimetry can be carried out. A radiation dosimeter is a device that measures either directly or indirectly, the quantities such as (1) exposure, (2) kerma, (3) absorbed dose or their time derivatives (rates), or related quantities of ionizing radiation. A dosimeter along with its reader is referred to as a dosimetry system.

There are different methods by which dosimetry can be carried out. One of the important methods is thermoluminicent (TLD) dosimetry. TLD's are certain crystalline substances used for the dosimetry. These dosimeters come in different shapes and types. Calcium Sulphate doped with Dysprosium ($CaSO4:Dy$) and Lithium Fluoride(LiF)[13] are some of the typical TLD dosimeters. They are available in the shape of powder, chips and rods. These substances when exposed to radiation absorb the energy and when heated re-emit energy as light which can be measured using appropriate measuring instruments.

Solid states diodes were also used as dosimeters where the dose absorbed can be directly converted to charge and calibrated to known dose. These are used for instant dose measurement. However its accuracy is less than thermoluminescent dosimeters. Most of the dosimetric studies in the present investigations have been carried out using thermo luminescent dosimeters

Dose at different points can be checked with computer planning system. Planning System helps to get an optimum plan before treatment of cancer. In this, the dose at different points can be measured. A 3D planning system allows viewing the tumour three dimensionally and helps to get a thorough planning without giving much dose to the normal tissue.

There are different methods by which absorbed dose can be calculated in a medium[14]. Accurate measurement of the dose received at any point allows to have a good planning and good result of radiotherapy treatment. Apart from accuracy of the dose at the point concerned, a uniform dose distribution within the target volume is also crucial for successful radiotherapy. The dose evaluation is especially necessary in the case of complex field geometry like head and neck fields and tangential field of breast treatment. It is generally accepted that variance in the dose delivered to the patient should be no more than 5% at the reference point[15]. Later in an ICRU report[16] it is recommended that dose homogeneity between -5%

and +7% of the prescribed dose throughout the Planned Target Volume (PTV) can be accepted.

To achieve this limit, thorough planning, setting of the patient in the machine and optimization of machine parameters are required. Dosimetric studies help verify the accuracy of dose delivery.

Most of the cancer cases are treated by radiotherapy. In some cases all the three important cancer treatment methods like surgery, chemotherapy and radiotherapy are used. Head and neck cancers, abdominal cancers and breast cancers are treated by radiotherapy. The site, shape and depth of the tumour make it necessary to do a dosimetry to deliver accurate dose to the tumour.

The present study confines to the breast cancer treatment and the dosimetry is carried out in the case of external beam therapy of carcinoma breast. The shape and site of the tumor require thorough planning and implementation. In the case of breast cancer, the contour of the patient and the under lying sensitive organs make it essential for careful planning of the treatment, for having good results.

INTRODUCTION TO SPECIFIC PROBLEMS OF STUDY

Breast Cancer is the second most common cancer, in women, in India after carcinoma cervix. Heyes et al[17] in their work reported that even low energy X-Rays in mammography, used for breast cancer screening program, may lead to breast cancer. Also it depends on the age of the patient at menarche, menopause and the first pregnancy. Later onset of menarche, which is associated with a delay in the beginning of regular cycles, suggests a 20% decrease in breast cancer risk for every year delayed. In the case of menopause, women below 45 years of age have a relative risk of 0.73 than women who developed menopause between the ages of 45 and 54. This information shows that it is the total duration of estrogen exposure that affects the risk of breast cancer[18].

The risk of breast cancer is also affected by factors that influence the hormonal cycles, including parity and the age at the birth of first child. Nulliparous woman and women who have first child after the age of 30 also are in the high risk group of breast cancer. In addition breast cancer is hereditary. Chance of women having breast cancer is high if she has a strong family history of breast cancer.

According to the extent of the disease there are different stages of disease. This staging is important to estimate the prognosis and the method of treatment. Both treatment and outcome are dependent on the stage and histological type of tumour.

Staging

There are two widely accepted staging systems for breast cancer. They are the American Joint Commission on Cancer (AJCC) – Union International Centre le Cancer (UICC) and the Columbia Clinical Classification (CCC). UICC, AJCC is commonly used in our country. This is based on TNM system. TNM system is Tumour, Node and Metastasis (TNM) system. Here, different stages of breast cancer are mentioned according to extension of tumour, nodal involvement and presence of metastasis. The staging is as shown below:

Primary Tumor (T)

TX	Primary tumor cannot be assessed
TO	No evidence of primary tumor
Tis	Carcinoma in situ: Interaductal carcinoma, labular carcinoma in Situ, or paget's disease of the nipple with no tumor
T1	Tumor of 2cm or less in greatest dimension
T1b	More than 0.5cm but not more than 1cm to greatest dimension
T2	Tumor more than 2cm but not more than 5cm to greatest Dimension
T3	Tumor more than 5cm in greatest Dimension
T4	Tumor of any size with direct extension to chest wall or skin
T4a	Extension to chest wall
T4b	Edema (including peau d'orange) or ulceration of the skin Of breast or satellite skin nodules confined to same breast
T4c	Both T4a and T4b
T4d	Inflammatory carcinoma

Lymph Node (N)

NX	Regional lymph nodes cannot be assessed (e.g. previously removed)
N0	No regional lymph node metastasis
N1	Metastasis to movable ipsilateral axillary lymph node(s)
N2	Metastasis to ipsilateral axillary lymph node(s) fixed to one another or to other structures
N3	Metastasis to ipsilateral internal mammary lymph node(s)

Pathologic Classification (pN)

pNX	Regional lymph nodes cannot be assured (e.g. previously removed, or not removed for pathologic study)
pN0	No regional lymph node metastasis
pN1	Metastasis to movable ipsilateral axillary lymph node (s)
pN1a	Only micrometastasis (none larger than 0.2cm)
pN1b	Metastasis to lymph nodes, any larger than 0.2cm
pN1bi	Metastasis in 1 to 3 lymph nodes, any nodes more than 0.2cm in size and all less than 2cm in greatest dimension
pN1bii	Metastasis to 4 or more lymph nodes, any nodes more than 0.2cm in size and all less than 2cm in greatest dimension
pN1biii	Extension of tumor beyond the capsule of a lymph nodes, metastasis less than 2cm in greatest dimension
pN1biv	Metastasis to a lymph node 2cm or more in greatest dimension
pN2	Metastasis to ipsilateral axillary lymph nodes that are fixed to one another or to other structures.
pN3	Metastasis to ipsilateral internal mammary lymph node(s)
	Distant Metastasis (M)
MX	Presence of distant metastasis cannot be assessed.
MO	No distant metastasis
M1	Distant metastasis (includes metastasis to ipsilateral supraclavicular lymph node (s)

Treatment of Carcinoma Breast

Radiotherapy is often used after surgery for breast cancer treatment. It may occasionally be used before or instead of surgery. In India usually, radiation is given to the affected breast after surgery. Though there is a controversy over the adjuvant radiotherapy that it decreases the lifespan of the patient due to radiation toxicity, modern techniques significantly decrease the incidence of local recurrence like cardiac morbidity and lung pneumonitis. Adjuvant radiotherapy is the radiation treatment given to the tumour after surgery, chemotherapy or both where as Chemotherapy is treatment using medicine.

Surgery is the definitive treatment for cancer and there are two types of surgery .One is mastectomy and the other is lumpectomy or Breast Conservative Surgery (BCS). Adjuvant chemotherapy is also given in most of the hospitals. The treatment depends on the stage of the decease. In mastectomy the whole breast is removed and in some cases axillary nodes are also removed. In Breast Conservative Surgery (BCS) only the tumour and some surrounding tissues are removed. Earlier, surgery was the only option for breast cancer. Radiotherapy is recommended in order to reduce local recurrence. It has been established that optimal tumour control could be achieved by routine post operative radiotherapy[19].

Radiotherapy is recommended following Breast Conservative Surgery and mastectomy. In the case of Breast Conservative Surgery is usually given to the breast tissue to reduce the risk of the cancer coming back in that area. After mastectomy the chest wall is given a radiation dose as a curative dose known as Radical dose. Palliative dose is the radiation dose for pain relief.

Radiotherapy after mastectomy

During the later part of 19th century radical mastectomy was the only choice for breast cancer treatment. In the mid of 20th century, breast conservation surgery has taken a leading role in breast cancer treatment. Around the same time it was found that post operative radiotherapy reduces the risk of local recurrence[20]. Until late 1970's post mastectomy radiotherapy was generally administered. Though this decreases local recurrence, it reduces the overall survival of patients. This is due to radiation toxicity like pneumonitis of lung and cardio toxicity. Lung and heart are the two important organs in the case of carcinoma breast. The radiation tolerance of sensitive organs depends on the volume of organs in the radiation field. For example, tissue tolerance [21, 22] of lung is 45Gy if 1/3 of the lung volume is involved, 30Gy if 2/3 is involved and 17.50gy if whole lung volume is involved. In the case of heart, the dose is 60Gy if 1/3 is involved, 45Gy if 2/3 is involved and 40Gy if whole heart volume is involved. However new methods help to reduce dose to the lung and heart significantly.

After mastectomy radiotherapy is given to the chest wall and appropriate draining regional nodes like axillary nodes and internal mammary nodes of the patient. The areas generally treated are chest wall, supraclavicular nodes and internal mammary nodes. The irradiation of internal mammary nodes depends on how much heart volume is in the radiation field, especially when cardiac toxicity is a concern[23]. Similarly a full axilla may not always be included after a thorough axillary dissection.

Usually the chest wall is treated with photon beams through tangential fields. Field given tangentially reduces the involvement of lung in the radiation field to a great extent. The tangential fields should be in such a way that, the superior border is the bottom of the head of the clavicle, medial border depends on whether or not the internal mammary chain is included for the treatment. The lateral border is usually the mid axillary line, which may encompass the mastectomy scar and the lower border is 1 to 2cm below the infra mammary fold.

If internal mammary chain is included, the medial border of the tangential field is extended across to 2 to 3 cm towards the contralateral beast (opposite breast) or match with the electron beam field in the case of electron beam therapy. If the internal mammary chain is not used, the medial border is midline, itself.

Electron beams are also used to treat the chest wall. Here the beam is given directly, with appropriate field size, to the chest wall. A larger field at the surface is necessary to cover a target area adequately. The energy of the electron beam should be in such a way that the target volume lies within the 90% of the isodose curve [24].

Radiotherapy after Breast Conservative Surgery

Breast Conservative Surgery (BCS) has become a widely accepted treatment option in the management of early stage breast cancer. The aim of irradiation of the intact breast is to eradicate macroscopic disease at the site of tumour. The advantage of this, over mastectomy, is good cosmetic results. Here primary tumour should have the size less than 4 to 5cm and there should not be any evidence of gross multi-centricity (tumour with more than one centre) or diffuse micro calcification on both pathology and mammography studies.

Radiotherapy after Breast Conservative Surgery (BCS) requires careful planning due to the complexity of the contour of patients. Here Radiation Therapy is conventionally delivered with tangential fields with wedges [25]. Wedges are devices for modifying dose distributions. They are of the shape of a wedge and made up of dense materials such as lead or steel mounted on a transparent tray. Wedge fields reduce the dose inhomogeneity within the treatment volume. Supra Clavicular Fossa (SCF) and axilla are treated separately. An additional booster dose is given by electron beam where ever it is necessary.

It is difficult to attain acceptable dose homogeneity across the whole breast in the case of conservative therapy. This is mainly due to the conditions like changes in the shape of the breast in multiplanes and the underlying organs. Careful planning is essential to achieve good results. There are controversies over the adjuvant radiotherapy in the case of carcinoma breast. It is observed that the adjuvant radiotherapy reduces local recurrence, but affects the over all survival rate of patients. The great concerns of adjuvant radiotherapy are mainly cardio vascular mortality after 15-20 years and lung relapse. New techniques of breast irradiation including conformal therapy and IMRT (Intensity Modulated Radiotherapy) have shown to reduce irradiation[26] of lung and Heart. The new treatment planning techniques using CT simulator and 3D planning improve the dose within the breast.

Conformal Radiotherapy and Intensity Modulated Radiotherapy reduce dose to the normal cells around the tumour and give high dose to the tumour. These are mainly used in the early stage of breast cancer and when Breast Cancer Surgery is done. Intensity Modulated Radiotherapy after Breast Conservative Surgery, helps to maximize tumour control while minimizing damage to normal tissues than wedged therapy[27]. The facilities of Intensity Modulated Radiotherapy and electron beam are available only with Linear accelerators used for radiotherapy. The cost of these machines, the staff and the time to spend on each patient confines this treatment to only a few centers especially in India. Some beam-modifying techniques, using devices like wedges and half beam block available in conventional cobalt machines, reduces dose to lung and underlying heart. But these extra blocks in the path of the beam and near the skin of the patient increases skin dose due to scattering[28].

Most of the patients come at a late stage of disease and added to this the IMRT and other new techniques are not available at a majority of the hospitals. Considering the cost factor and dearth of facilities of new techniques, conventional five field or four field techniques in the cobalt therapy machines are usually used in most places.

Brachytherapy method is also useful in the case of chest wall irradiation. A careful planning is necessary for this technique. This technique gives very high dose to the tumour while the dose decreases very fast as the distance from the tumour or source increases. A small deviation from the path may give high dose to normal cells and sensitive organs and less dose to the tumour. This affects the functioning of lung and heart adversely.

At Calicut Medical College there are about 250-300 breast cancer patients coming for radiotherapy treatment every year. Radiotherapy Department of Calicut Medical College occupies second place in the number of cancer patients for Radiotherapy treatment after Regional Cancer Centre, Thiruvananthapuram. Most of the Breast cancer patients coming for the treatment are of stage II or stage III. All the three methods like surgery, chemotherapy and radiotherapy are used for the treatment. Ninety five percentage of these cases are treated with radical mastectomy in the Radiotherapy Department of Calicut Medical College where two cobalt machines are available for the treatment. The present study of the dosimetry in carcinoma breast is carried out mainly with cobalt machines.

Usually a conventional treatment with 4 field -5field technique is given for radiotherapy after mastectomy. This is to give the necessary dose to the chest wall in order to reduce the local recurrence.

A dose of 5000cGy in 25 to 28 fractions over five and half weeks is usually used for the treatment of chest wall. Electrons are used to minimize dose to underlying organs like lung and heart. The electron energy is determined with the help of Computed Tomography treatment planning system to achieve 90% depth dose at 3 to 4cm. As large area of electron beams are used for the treatment, skin dose is high in some patients. To avoid this photon-electron- beam mix is also used. In this case a portion of the total dose is given with electron beam and the remaining dose with photon beam.

To irradiate supraclavicular and axillary nodes, single antereoposterior photon field is usually used. In some cases full axilla is not included in the field[29]. The field is setup in such a way that it includes midline, coracoid process, the head of the clavicular, the superior boarder of the chest wall. In this approach, radiation to trachea, esophagus, spinal chord and larynx has to be avoided [30]. For this either angled beam or blocks, to protect these organs, are used. Usually 5000cGy in 25-28 fractions at a depth of 3-5 cm are used for the treatment of nodes.

For most patients irradiation of the full axilla will require additional separate posterior axillary port. In our laboratory, a single dose is given as posterior axillary dose.

Carcinoma breast is treated in conventional method with 4 field or 5 field techniques. This shows the complexity of the treatment in the case of Ca-breast. The treatment with radiation should never cause the radiation toxicity which affects the survival of the patient.

In mastectomy, the chest wall is treated with two tangential radiation fields. Supraclavicular Fossa is treated with Anterior Posterior (AP) field and post axilla with a single surface dose method. In some cases internal mammary chain is treated separately. Dose homogeneity is difficult in the complex geometry of the breast. A dosimetry helps to verify whether these points received the prescribed dose. In modern techniques where Breast

Cancer Surgery is common, the uniformity is more complex. The dose to the affected breast is not uniform through out the volume if we treat with conventional therapy. Wedged techniques, conformal therapy, Intensity Modulated Radiotherapy (IMRT) help to give a uniform dose to the target volume. A thorough treatment planning is necessary to achieve the goal.

In the case of mastectomy, electron beam can also be used for treating the chest wall. The energy of the electron beam is selected according to the depth of the tumour bed which is the chest wall in the case of radical mastectomy of carcinoma breast. The dose should be uniform through out the tumour bed. The percentage of dose distribution which is given by an isodose line is taken for the dose calculation. Isodose line is the line which joins the points having the same dose. It is usually prescribed in percentage.

Electron beam can be given along with photon beam which is used to irradiate Supra Clavicular Fossa. A 3D planning system helps to find the best dose distribution which gives less dose to lung and heart and high dose to tumour bed[31].

In the case of Radiotherapy after Breast Conservative Surgery photons of 6MV are used for tangential beam and for axillary nodes if the nodes are to be treated. A booster dose is also given in areas wherever it is found that the dose is below the required value. This booster dose is given with smaller field to the area where the dose is found to be inadequate. This booster dose is given either with photons or with electrons. The combined dose distribution has to be viewed before the treatment. The thermoluminescent discs help to measure dosed at different points on the breast tissue.

The complexity of shape, size of the target volume, necessitate for a thorough dosimetry in the case of breast cancer treatment. The upper part of lung will be lying under the chest at about 2cm. Therefore a tangential field may include a good part of lung in the radiation field. As lung tissues are very sensitive to radiation, lung pneumonitis is a sure after affect of radiation[32].The volume of the lung in the field has to be reduced as much as possible as the affects of radiation to lung depends on the volume of lung in the radiation field. A dosimetric evaluation of dose at different points, in the breast volume helps to find out the dose in lung and also whether the chest wall receives uniform dose or not.

If the cancer is in the left breast, a large volume of the heart will also be present in the radiation field. A half beam block treatment helps to reduce the dose to heart as well as to the lung.

The dose distribution should be homogenous to avoid areas of under dose or over dose, which result in insufficient tumour control, or late affects (fibrosis) and poor cosmetics. The two parameters which need careful consideration for treatment plans of breast radiotherapy are (1) the accuracy of the dose calculation and (2) the homogeneity of the dose distribution. In addition to tangential fields, separate fields are given to the effected nodes. The radiation treatment to internal mammary (IM) nodes and extent to which axillary nodes are to be treated depends on clinical situations. If the nodes are to be treated, a separate radiation field is used for it. The radiation beams diverge as the distance increases from the source. Accordingly, there is a chance of crossing over of the two fields at a point on the patient surface if two fields are used. This causes high radiation at some areas or spots. These are known as hotspots. To avoid these hotspots beam separation can be used. However, this separation of beams causes lesser dose on the patient where the two field separation exists. This is usually known as cold spot. Therefore a separate field may cause either a hot spot or cold spot resulting in strong or weak dose at the margin where the two fields meet. Dosimetry with thermoluminescent dosimeters or with treatment planning systems helps to find out this dose inhomogeneity in this area.

Now a days, New Techniques of treatment are available. Linaer accelerators are available in Regional Cancer Center (RCC), Trivandrum, India and Amrita Institute of medical Sciences (AIMS), Kochi, India. Some of the breast cancer patients are treated at these institutions, while majority of the cases are treated in the hospitals attached to the various Medical Colleges. The accelerators, Computed Tomography simulators and 3D planning system help to give an accurate high dose to the tumour reducing at the same time dose to lung, heart and other normal cells.

It is long known that Low energy radiation will cause late effects[33]. When one breast is treated for cancer, there is a very high possibility for the other breast to get low radiation. This contralateral breast dose from primary breast irradiation has been found to be one of the main sources of secondary breast malignancies[34, 35]. A half beam block, and wedge increase the electron contamination to skin and hence increases dose to the contralateral breast [36]. The dose to contralateral breast can be reduced if the distance from the block is increased.

In the present investigations, we measured doses at different points in affected and contralateral breasts with conventional techniques as well as some new techniques of irradiation. The study was carried out with different therapy machines for comparison of dose in different machines and techniques.

REVIEW OF LITERATURE

Though Breast cancer is common, it is complicated from the point of view of treatment. The complexity is due to the shape of the breast and other organs near the tumour. Accordingly, extensive investigations have been carried out by several researchers across the globe to optimize the dose and reduce the side effects on the other organs.

Evaluation of Intensity modulated tangential Beam verses conventional tangential irradiation for Breast Cancer was reported by Huang et al[27]. They Compared the Intensity Modulated Radiotherapy with wedged tangential field techniques. Huang measurements show Intensity Modulated Radiotherapy technique improves dose homogeneity through out the target volume of intact breast and reduces the dose to other organs. Bhatnagar et al[37]in their work with Intensity Modulated Radiotherapy technique reported that the primary breast size significantly affects the scattered dose to the contra lateral breast but not the ipsilateral lung or heart dose . Butler et al.[38]compared different techniques of radiotherapy for chest wall irradiation in the case of Breast Cancer . They suggested that the choice of technique should be based upon clinical discretion. In most of the centers in India, modern techniques are not available. Usually chest wall irradiation with conventional 4 or 5 fields is used. Donovan et al [39] developed a simple method to analyze anatomical dose distribution in the breast volume of 800 patients treated with either standard wedged technique or intensity modulated radiation therapy. They reported that Intensity modulated radiation therapy gives more dose homogeneity than wedged technique. Ma et al[40] carried out a comparative dosimetric study on tangential photon beams in Intensity Modulated Radiotherapy (IMRT) and modulated electron radiotherapy (MERT) for breast cancer treatment. A 5 Grey reduction in maximum dose to lung and heart is found over conventional method, when Intensity Modulated Radiotherapy is used. A reduction of dose up to 20Grey to lung and heart could be achieved by MERT over conventional methods. Orecchia et al[29] in their work reached the conclusion that therapeutic doses are not really delivered to first level axillary nodes by standard tangential fields and so a specific treatment planning and beam arrangement are required when adequate coverage is necessary.

Rufus et al[30] evaluated the results of five field technique in breast cancer using computed tomography image for planning. The five field technique described in their work provided good coverage to the breast and regional nodes with acceptable limits on toxicity and without requiring 3D treatment planning of Intensity Modulated Radiotherapy. Aref et al[31] brought out the importance of three dimensional planning in carcinoma breast to improve dosimetry. They evaluated the dosimetric differences between a simple radiation therapy plan utilizing a single contour and a more complex three dimensional (3D) plan utilizing multiple contours, lung inhomogeneity correction and dose based compensators. The 3D plan with multiple contours helps to achieve a better dose homogeneity. Larry et al[3] in their work based on initial clinical experience showed that Intensity Modulation helps to improve dose uniformity with tangential breast radiotherapy. A comparison of different intensity modulation treatment techniques for tangential breast irradiation is carried out by Chang et al[25]. In their work, the intensity modulation was achieved by wedges, compensators and multi-leaf collimators (MLC). Uniformity could be achieved with these compensators and Multi-leaf collimators and the contralateral dose in these cases was less compared to the wedge technique. Their work also showed that the multi-leaf collimators (MLC)-Intensity Modulated (IM) technique requires the largest irradiation time with virtual wedge and compensator while IM techniques required the least. Hounsell et al[28]evaluated electron beam contamination and build up doses in conformal radiotherapy fields where multi-leaves are used. The dose in the build up region depends upon the primary photon beam, back scattered radiation from the patient and contamination radiation from outside the patient. A model based measurement is carried out with primary component and contamination component of the beam. An exponential form with build up for higher energies was obtained.

There is a controversy over the role of adjuvant radiotherapy on the overall survival of the patient. Extensive work has been done in this area. WolfgangJanni et al[20], reported a reduction of risk of local recurrence by adjuvant radiotherapy in early stage cases. However, there is no impact on the over all survival of the patient. Kunkler[26] showed that adjuvant radiotherapy increases the cardiac morbidity and mortality induced by radiation especially in left sided breast cancer patients. New methods with new versions of treatment techniques using Multiple Leaf Collimators, and 3D planning systems reduce dose to the heart. A more comprehensive study is needed for better understanding of these results. Violet et al[19] explained that in the case of treatment of early breast cancer, adjuvant irradiation improves local control following mastectomy and breast conserving surgery. Though radio toxicity is present in adjuvant radiotherapy, a greater homogeneity of dose distribution as well as reduced cardiac and lung irradiation are possible with modern techniques. The homogeneity can be increased by using compensators also. The study by Wilks et al[41] shows that combinations of compensators improve dose homogeneity for tangential breast fields. Neal et al[36] in their review state that even with advanced techniques, dose inhomogeneity is present in breasts.

Dosimetry is the best method to ensure the dose homogeneity. There are different methods to do the dosimetry in tissues as well as in phantoms which are tissue equivalent material. Stochioiu et al [4] developed Dysprosium doped CaSO4 detectors for high sensitivity X- and Gamma rays detectors. The basic dosimetric parameters of the detectors, measured according to the international requirements, are superior to the reported literature data and fully accomplish the standardization requirements. Bhatt et al[42] explained that Thermoluminescent (TL) dosimeters have become a versatile system of dosimeters for assessment of dose in clinical applications of ionizing radiation. The advantages of TL dosimeters include high sensitivity, miniature size, tissue equivalence, low fading, re-usability and linear dose response. Being a passive device, TL dosimetry provides an easy way for inter comparison of dose from different institutions.

An anthropomorphic breast phantom is developed for dosimetry by Becomo et al[43] for the breast treatment process. This helps to do dosimetry with thermoluminescent dosimeters for quality assurance and dose verification.

Dose to the contralateral breast also affects the long term survival of the patients as it has a chance of causing cancer in that breast. In a study Heyes et al[17] reported that even low energy radiation from sources can cause late affects like breast cancer. Johnson [44] showed that irradiation of cancerous breast causes dose to contralateral breast which results in cancer in that breast at a later time.

Storm et al [33] explained the affect of radiation in contra lateral breast. Frass, Roberson and Lichtes[45] measured dose to the contralateral breast due to primary breast irradiation and showed that contralateral breast dose causes malignancy in that breast.

Chougulee, Hussain et al. [46] conducted measurements of contralateral Breast doses due to primary breast irradiation for malignancy. A total dose of 111.25 to 223.5cGy without HBB is received by contra lateral breast in their measurement of breast doses due to primary irradiation for malignancy. Ramachandran and Nair[47], in their work on Contralateral breast dose measurement in patients treated with radiation for breast cancer procedure found a contra lateral dose of 99 to 608 cGy due to all fields for complete treatment.

Tercilla, Krasin, and Lawn-Tsaoc[35] state that half beam block though decreases dose to heart increases contralateral breast dose. Kelly et al[48] also showed use of wedge and, half beam block gives more dose to contralateral breast. The lowest contralateral breast dose is with the asymmetric jaw with no medial wedge and block. Warlick et al[49] found that dose to contralateral breast is more when an external standard wedge is used.

Solid state detectors can also be used for dosimetry. Though thermoluminescent dosimetry gives more accurate value, Solid state detectors give instantaneous results. Rakesh Kumar, Rajasekhar, and Dinesh Kumar [50] carried out on line Diode Dosimetry using diodes made by PC Rainbow, on Breast Conservation Therapy where in the dosimetry is done using diode detector which is simple to use and get instantaneous results.

The inclusion of internal mammary nodes for the treatment mainly depends on the decision of the treating oncologist. Severin, and Connors[51] et al. compared partially wide tangent (PWT)treatment which include internal mammary chain and other standard techniques. PWT treats internal mammary chain with some acceptable toxicity to heart. However, it gives more doses to heart than other standard techniques. Poortmans et al [23] reported that radiotherapy to internal mammary chain increases dose to the heart.

There are number of studies to improve the dose distribution in breast cancer. Narayan, Sherly Saju et al. [52] reported a new centre point for dose presumption, which gives homogenous dose distribution to entire chest wall. Lung correction in breast cancer helps to reduce dose to lung as the dose absorption in lung tissues and normal tissues is different. Dose absorption in lung is less and so the normal tissue at the opposite side of lung tissue gets more radiation. High dose to lung causes lung pneumonitis. Ravindra[53] explained that the dose evaluation will not be accurate if lung correction is not applied while considering the interfiled separation. Surendran, et al[54] in an analysis of lung dose in various Techniques for the treatment of breast cancer studied dose at different points by tangential open fields, tangential wedged fields with a cobalt machine Gammarex-R made by Wipro GE. Isodose curves are used to find the dose to lung. They also analyzed the lung dose of various techniques for the treatment of Breast Cancer.

A new method like breath hold therapy helps to reduce lung volume in the field of treatment. This is a new technique and research is going on in this field. Remouchamps et al [55] reported in their work about significant reduction in heart and lung doses using deep inspiration breath hold with active breathing control and intensity modulated radiation therapy for patients treated with breast irradiation. Breath hold therapy helps to reduce the amount of lung volume and heart volume in the radiation field.

Another method of giving boost dose other than electron beam treatment is by brachytherapy. Christophe Hennnequin[2]explained the role of high dose rate brachytherapy . High-Dose rate Brachytherapy for early breast cancer allows boost dose to be given on an outpatient basis. It gives the same local control as other boost techniques for localized breast cancer with acceptable cosmetic results.

Small et al [39] compared conservative therapy and modified radical mastectomy for early stage breast cancer. This study shows similar survival rates in both cases. Moritz et al[56] observed Mastectomy rates for similar tumors vary widely. The treatment techniques vary with oncologists and surgeons.

Radiation physics has an important role in the improvement of dosimetry in all radiation therapy cases. Seaby [57] designed a multiblock phantom for dosimetry study which can be used to a variety of dosimetry work.

Zhou et al [58] in their studies on younger and older women treated for breast cancer, compared the out come of the treatment and found that the effect on the younger women is more drastic than in the older women. This is mainly due to the dose to the contralateral breast. Muller-Runkel et al[59] studied contralateral dose and explained that the dose to contralateral breast should be reduced by using a shield made of vinyl coated flexible lead. They used a phantom and thermoluminescent detector to find the dose.

Much of the reported works are in the intensity modulated radiotherapy and other modern techniques. Most modern machines are having these facilities and the field is still developing. Development of computer aided techniques has radically improved the measurement techniques. In developing countries it is not easy to acquire such sophisticated equipments considering the costs involved. Most of the treatments are carried out with cobalt machines. Dosimetry helps to improve the dose homogeneity in the target volume of tumour and reduces dose to normal cells and is essential for cancer treatment using radiations.

MOTIVATION FOR THE WORK UNDER TAKEN

Breast cancer is one of the major cancers in women. At Medical College hospitals our experience is that about 7-8% of cancer patients coming for treatment are breast cancer patients.

There are mainly three approaches for the treatment of breast cancer, viz. (1) surgery, (2) chemotherapy and (3) radiotherapy. In the earlier days surgery was the only option for breast cancer treatment. In some cases Chemotherapy was also given together with surgery.

Violet et al [19], demonstrated that an adjuvant radiotherapy helps to reduce the local recurrence of the disease. In lumpectomy as well as in mastectomy, radiotherapy to the remaining tissue reduces the local recurrence and improves the chances of long term survival.

With respect to the most other common cancers, a high local control rate and good overall survival can be achieved for the majority of the breast cancer patients with current surgery and adjuvant radiotherapy.

Radiotherapy is given after mastectomy and also after Breast Conservative Surgery to the breast tumour. In the case of Breast Conservative Surgery where the tumor size is small and nodal involvement is also small, radiotherapy decreases local recurrence and also reduces the long term chances of death from the diseases.

It is found that in breast cancer the lymph nodes in the armpits are affected and have to be given radiation. If the breast cancer has already spread to the lymph nodes in the armpit, then radiotherapy can again produce sustained reduction in chances of local recurrence and improve the chances of long term survival. Therefore it is clear that patient who under goes Breast Conservative Surgery should have adjuvant radiotherapy to avoid local recurrence and patients who had mastectomy, could have radiotherapy with the advice of the oncologist.

In India, it is found that about 80% of the breast cancer cases are of stage II or stage III diseases. In our institution (Medical College, Calicut, India) 90-95% of cases are of stage II or stage III of carcinoma breast. The oncologists prefer mastectomy for these cases. After mastectomy radiotherapy is given to the chest wall, supra clavicular fossa and axilla in these cases. The economic considerations force many a hospital to go for cobalt machine treatment methods instead of newer techniques of radiotherapy, considering the cost.

Cobalt therapy machines give photon beam for radiation. As the average energy of the gamma radiation is 1.25MeV, the radiation goes to depths in the tissue while irradiating the tumour. For chest wall irradiation, such depth dose is not required for the therapy. Therefore the gamma (γ) radiation is given tangentially to the chest wall.

A thorough review of the literature shows that most of the measurements are concerned with Intensity Modulated Radiotherapy only which helps to reduce radiation to lung, heart and other normal tissues while give high dose to the tumour. The Intensity Modulated Radiotherapy technique is mainly given in the case of Breast Conservative Surgery.

In India only few centers do Intensity Modulated Radiotherapy. In Kerala, for breast cancer cases particularly, Intensity Modulated Radiotherapy is not given. However in many centers electron therapy and conformal therapy are also used.

From the works reported, it is seen that in the case of breast cancer homogenous distribution of dose is difficult because of the shape of the treatment volume, the normal tissues surrounding it and other sensitive organs [38]. A thorough dosimetry helps to find out whether the target volume gets the required dose while lung, heart etc get lesser dose.

Dosimetry can be carried out by different methods. In treatment planning system we can see the dose at different points and volume. The treatment planning system which is fed with the data from the treatment therapy machines give the dose at points of interest. These are the theoretical values of dose at these points. The dose at points outside the treatment volume is difficult to find out, if we do not enter the required data and contour. In this case a thermoluminescent dosimetry helps to find the dose at these points.

Dosimeters having small sizes can be placed at different points on patients to get the dose at these points. Thermoluminescent dosimeters and diode detectors are used for such purposes.

It is necessary that the dose variation should be within 5 to 7.0%. A deviation from this may lead to cold or hot spots in the radiation volume. This will cause local recurrence or unnecessary high dose to tumour and other organs.

At Medical College hospital our experience is that about 7-8% of cancer patients are seen with recurrence like, brain metastasis, immobilization of hand and spine metastasis. This data is from the patients who come for follow up action. Most of the patients are not coming for follow up after treatment is completed. Therefore we cannot estimate the exact percentage, of the patients, who have the recurrence. This recurrence may be due to missing of tumour during irradiation or with inadequate dose to some volume of tumour. Dosimetry helps to avoid such problems.

A dose volume histogram can also help to find the dose homogeneity in target volume and other normal tissues [50]

Radiotherapy is an important treatment method for patients with breast cancer. With respect to most other common cancers, a high local control rate and good over all survival can be achieved for a majority of breast cancer patients with surgery and adjuvant radiotherapy techniques.

As the incidence of breast cancer is high, even small improvement in the radiotherapy treatment can still have a significant impact on the control of the disease. Complex geometry of the target volume and the presence of sensitive organs need a thorough dosimetry to achieve the goal.

A comparison of treatment methods with different machines using dosimetry allows us in improving the treatment techniques. The critical parameters of treatment plans for breast radiotherapy are the accuracy of the dose calculation, the homogeneity of dose distribution as represented by the treatment plan and the inclusion of correction for inhomogeneities wherever necessary.

A close scrutiny of literature clearly shows that there is a controversy about the adjuvant radiotherapy after the surgery, that it reduces the overall survival chances of patients. Radio toxicity like cardiac effect, lung effect and poor cosmetics effects make the oncologist think twice before referring the patient for radiation. In all these cases it is necessary to optimize the dose delivered to the cancer tissues.

It was therefore decided to undertake a systematic study of dosimetry in the carcinoma breast patients. The present study was carried out mainly with cobalt therapy machines. However data from accelerator measurements is also used for comparison sake.

Chapter 2 gives the working principle of the various machines and the instruments used in the present study. Different methods for doing dosimetry with different machines are also explained in details in this chapter.

Chapter3 gives the results of dose variation between measured value and calculated ones. A comparison is done between different machines and different treatment techniques.

Finally the implications and justifications of the present investigations are given in **Chapter 4**.

MATERIALS AND METHODS

Sushama.P "Study of dosimetry in various cases in Radiotherapy" Thesis.
Department of Physics, University of Calicut, 2007

CHAPTER - 2

MATERIALS AND METHODS

MATERIALS AND METHODS

Usually in India 90% of the breast cancer cases are of second or third stage cases. Other cases are advanced ones. In all these cases axillary nodes are also treated with photon beam.

In our laboratory there are two groups of oncologists for radiation therapy (Unit I & Unit II) who adopt different approaches for the treatment. The treatment is planned by therapists and physicists while radiographers actually deliver the dose to the patients. Most of the breast cancer cases are radical mastectomy cases where the radiation is given to the chest wall. A pair of tangential fields is skimmed across the chest wall to cover the whole breast bed following mastectomy. The total dose of radiation usually used is 40-50Gy in 20-30 fractions over a period of 4-5 weeks at 5 days per week as established from numerous clinical trials[9] to achieve loco-regional control while keeping complications at the acceptable level. In one of the units in our laboratory, tangential field dose used is 50Gy which is given in 28-30 fractions while in the other unit it is 40Gy given in 20 fractions. It is preferable that the dose per fraction is less than or equal to 200cGy, to reduce the cardiac morbidity as much as possible.

The incidence of relapse happens if Supra Clavicular Fossa (SCF) is not treated, in breast cancer patients. Therefore Supra Clavicular Fossa is treated with radiotherapy. Unit I prescribes 50Gy in 28 fractions while unit II prescribes 45Gy in 20 fraction as surface doses to this region.

The involvement of internal mammary (IM) lymph node chain will also affect the survival of carcinoma breast patients. A separate radiation using photon beam as on field treatment to the internal mammary chain may give more dose to lung and heart[18]. This causes radiation toxicity in lung and heart and affects the survival of patients. Therefore in some cases the radiation to these nodes is given along with the tangential field itself. In our laboratory, unit I gives a separate single small field radiation to internal mammary chain while the unit II includes the nodes in the tangential field itself.

The prescribed dose is given using the two Theratron 780E and Elite 100 cobalt therapy machines, which are very similar in technical aspects. The essential difference between the two machines is in their source to axis distance.

Theratron 780E

The therapy source used in Theratron 780E is cobalt- 60 **(fig1)** of activity 417TBq (as on April1998). The source is sealed inside two stainless steel capsules having 2cm diameter and 3 cm length.The cobalt -60 nuclei continuously and spontaneously decay to nickel 60 nuclei while emitting beta (β), gamma (Υ) radiations. The half life of cobalt-60 source is 5.26 years. The Gammma (Υ) photons from this source is used for cancer treatment.

There are mainly 3 parts in the machine. 1. source head, where source is housed 2. Gantry – which is rotating in 360^{O} about an axis – 3.The couch on which the patient will be lying during the treatment. The machine and couch are isocentric. The distance of the source from the isocentre in the case of Theratron 780E is 80cm. The source head and table motions are controlled with a hand control in the treatment room. The control panel of the machine which is out side the treatment room is of digital model. In addition to a panel for entering the treatment parameters on the control panel, it features alarms and interlock systems for security considerations. The interlock system restricts the entry of people into the treatment room when the source is switched on. A key switch controls the power supply of the unit.

34·A 8

Figure 1 - Theratron 780E Cobalt- 60 Therapy Machine

This machine can be used for wedge treatment, rotation therapy and arc treatments. In the case of breast radiotherapy a half beam block is used, which is made up of 5cm thick lead, to block half of the field in order to reduce dose to the lung and heart.

Elite 100

It is similar to Theratron 780E. The main difference is the distance of isocentre from the source. This distance is 100cm. The control panel is computer controlled. The double encapsulated source has a stainless steel outer capsule. The radioactive content is in the form of plated cobalt pellets. The activity of the source is 436.6 TBq (as on 19-12-2003). Elite 100 **(fig2)** is also having wedges and a half beam block. This machine is also used for treating breast cancer.

All the mastectomy as well as Breast Conservative Surgery cases are treated by 5 field techniques. Irradiation of the chest wall after mastectomy is accomplished with tangential photon beams. A separate supra clavicular field and axiliary boost is given for nodes.

The treatment technique is same in both the cobalt machines. The dose is found at the centre of the tumour using SSD (Source to surface distance) technique. In the case of chest wall, the mid point of the line joining the two tangential field centers is used as the dose prescription point. According to the interfiled distance or the size of the chest wall to be treated the surface dose changes. Using percentage depth dose methods the dose on the surface is calculated. Treatment time is estimated using the output which is measured in the unit of cGy/minute of the machine. The dose output of the Cobalt machine is constant as it uses a radioactive isotope for a source, unlike in an accelerator. The outputs of the two cobalt machines are different according to the activity of the isotope. Usually the output is measured at the isocentre of the machine. As the distance of the isocentre

Figure 2 - Elite 100 Cobalt- 60 Therapy Machine

from source is different for the two cobalt machines used in the present study it affects the output of these machines.

The dose measurement at different points of interest in the case of carcinoma breast treatments depends on the dose output of the machine. Therefore it is very essential to find out the different physical parameters of the machines.

Verification of physical data of machines

Cobalt machines

Most of the studies were conducted using the two Cobalt – 60 therapy machines in our laboratory, namely Theratron 780E and Elite100. One of the machines is having source to axis distance of (SAD) 80cm and the other is having distance of 100cm. Before doing dosimetry, it is necessary to see that these machines give the constant output. For this the machine has to be calibrated at the beginning.

Both the cobalt therapy machines are calibrated using secondary standard dosimeter which is made by the C-D high tech, India. The output of the machine is measured using water phantom as shown in the **fig 3**. The water phantom having a volume of 35cmx35cmx35cm is also made by CD high tech, India. The dosimeter used is of ionization model with volume of 0.6cc and is kept 5cm below water level for the exposure. The readings are taken for different field sizes. The output of the machine is found out using the formula[60].

$$D = M\, N_{d,water}\, k_{tp}$$

Where,

D - dose in water

M - reading in electrometer

$N_{d,water}$ - absorbed dose to water factor

k_{tp} - Temperature Pressure correction

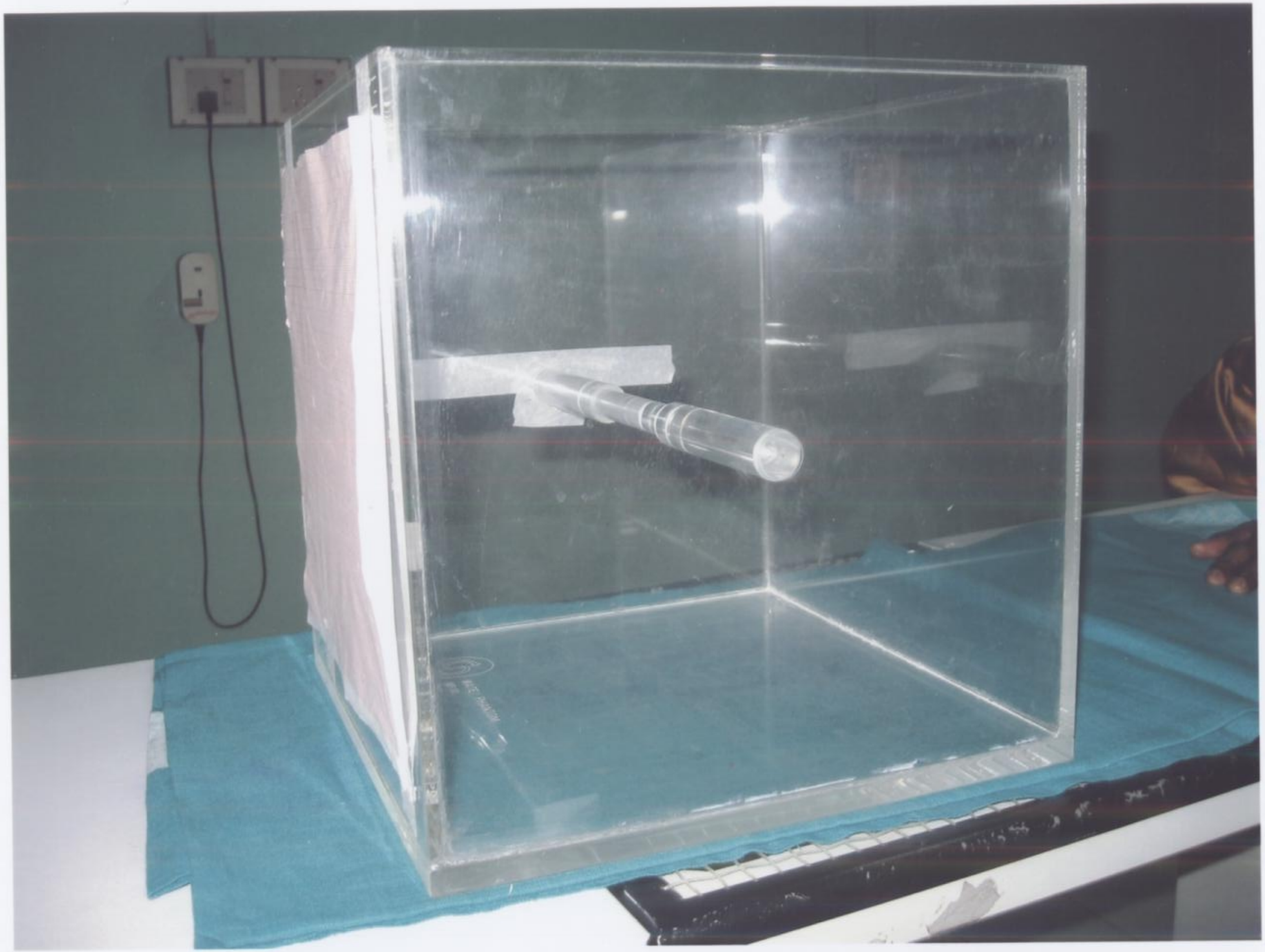


Figure 3 - The water phantom having a volume of 35cmx35cmx35cm is also made by CD high tech

We have used half beam block for most of the cases. It is necessary to check for the efficiency of the block in shielding. For measuring the efficiency, and dosimetry in patients, we have employed solid state detectors and thermoluminescent dosimeters.

Linear Accelerators

Linear accelerator of model Elekta Precise **(fig 4)** made in UK was also used in the present investigation. Here the half beam block is not used for the treatment. Multi-leaf collimators are used to define fields. The calibration of the accelerator is a strenuous process. It is done usually with Radiation Field Analyzer (RFA). Everyday before starting the treatment the consistency of the output had been verified.

Before making the actual measurements, thermoluminescent dosimeters and the reader were calibrated

Thermo luminescent material

Luminescence is the term used to describe the light emitting properties of a material. Some materials, upon absorption of radiation retain part of the absorbed energy in metastable states. When this energy is subsequently released in the form of ultraviolet, visible or infrared light, the phenomenon is called luminescence. All forms of luminescence are of same process by which a material with a small quantity of dopant is excited and trapped in a higher energy state. Two types of luminescence, fluorescence and phosphorescence, are known, which depend on the time delay between stimulation and the emission of light. Fluorescence occurs with a time delay of between 10^{-10} and 10^{-8} s; phosphorescence occurs with a time delay exceeding 10^{-8} s. The process of phosphorescence can be accelerated with a suitable excitation in the form of heat or light. When de-excited and goes back to the low energy state, it releases the excess of energy in the form of a

Figure 4- Elekta Precise Linear Accelerator

photon of light. If the exciting agent is heat, the phenomenon is known as thermo luminescence and the material is called a thermoluminescent material, or a TLD when used for purposes of dosimetry.

All thermoluminescent (TL) materials **(fig 5)** are crystalline substances. In the crystal lattice of materials electrons are in energy bands. There are allowed energy bands and forbidden energy bands. The presence of impurities in crystal creates energy traps in the forbidden region and provides metastable states for electrons. When material is irradiated some of the electrons in the valence band receive sufficient energy to be raised to the conduction band. The electron and the hole thus created move independently through their respective bands until they recombine or fall into a trap. This is a metastable state. If there is instantaneous emission of light, the phenomenon is called fluorescence. If an electron in the trap requires energy to get out of the trap and falls to the valence band, the emission of light is phosphorescence. At room temperature the phosphorescence is takes long time. It can be speeded up by heating the material. The phosphorescence produced by heating the material is thermo luminescence. When this thermoluminescent material is exposed to radiation, the electrons are excited and trapped in a higher energy state and it gives out the energy only when it is heated.

$CaSO_4$: Dy thermo luminescent discs were used in the present study. The main requirements imposed to a thermoluminescent phosphor are (1) a high efficiency or sensitivity $(\eta_{TL})=E_{TL}/mD$, where E_{TL} is the energy emitted as luminescence, m is the phosphor mass and D is the absorbed dose value, (2)good dosimetric properties, such as linear response for a large interval of doses,(3) reproducibility and insensitivity to temperature, light and humidity (4) easy to be handled. Generally one thermoluminescent material cannot accomplish all these requirements at the same time. This is the reason why an activator or dopant is added with the thermoluminescent material. $CaSO_4$ becomes Thermoluminescent when an activator such as dysprosium, is

Figure 5 - $CaSO_4$: Dy thermo luminescent discs

added in the crystalline structure. The energy of ionizing radiation, stored in the material after its irradiation can be maintained for a three month period, with a fading value of less than 5%. The energy stored in a $CaSO_4$: Dy is released as a light signal after its heating to a temperature of 360^0C. $CaSO_4$: Dy dosimeters are used for the measurement of absorbed dose of energy within the range of 30keV to 3MeV. New thermoluminescent dosimeter chips were cleaned and annealed before using them for dosimetry.

Cleaning

It is important to clean the chips before dosimetry as dust and impurities on the surface of discs affects the sensitivity of thermoluminescent chips. Thermo luminescent discs were cleaned by immersing them in high-grade acetone for an hour and then rinsing in the distilled water. After rinsing, these discs were dried in a metal tray for sufficient time.

Annealing

Annealing is important in the case of thermo luminescent material as the output for any given exposure depends on:

- The temperature at which the material is heated before and after exposure.
- The rate at which the material is heated before and after the exposure.
- The rate at which the temperature is cooled before and after the exposure.

Dried discs were spread evenly by keeping another glass plate over them. They were then kept in air circulation in an oven Thermolyne by USA **(fig 6)** at room temperature. The temperature of the oven can be increased from 0^0C to 300^0C. The temperature was increased to 360^0C and the discs

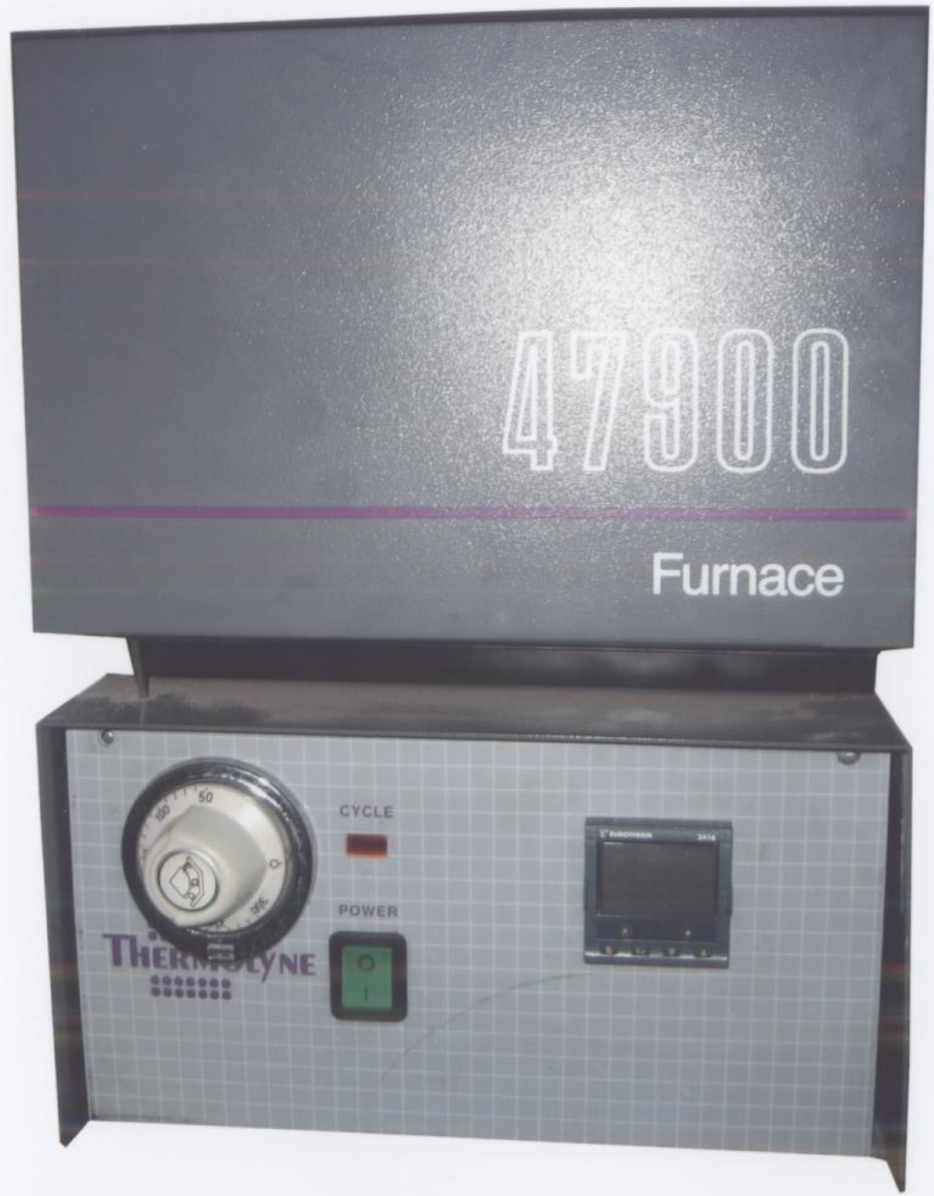


Figure 6 - furnace 'Thermolyne'

were kept at that temperature for about1 hour. After one hour when the temperature reached 50^{0}C or 60^{0}C the discs were removed.

Calibration of Thermoluminescent dosimeter reader

It is very important to see that the thermoluminescent dosimeter instrument reads a given thermoluminescent chips consistently. For assuring the same dose the thermoluminescent dosimeter reader was calibrated first. Before calibrating the thermoluminescent dosimeter reader the thermoluminescent dosimeter chips were selected based on the consistency of the output. Thermoluminescent dosimeter chips may give different readings with same exposure dose. This is due to manufacturing defects. Therefore thermoluminescent dosimeter chips, which give same readings, were kept as separate batches.

Each thermoluminescent dosimeter within a given batch has a different sensitivity. As a rule, it is expected to see a spread in sensitivities up to ±15% about the average of a batch.

The purpose of a thermoluminescent dosimeters reader is to measure the output of thermo luminescent samples. The reader used in the present study is Victoreen 2800M thermoluminescent dosimeters reader, manufactured in USA **(fig 7)**. It has a heater pan, heater control circuit to heat the sample, a photomultiplier tube to collect the light and an electrometer to measure the small current generated by Photo multiplier tube.

The heater heats the thermoluminescent dosimeter chips, which emits the radiation captured by it during the exposure. This light output which is very low is amplified with the help of a photomultiplier tube so that the dose absorbed by thermoluminescent dosimeters can be read out by the electro meter.

Figure 7- 2800M Victoreen thermoluminescent dosimeters reader

Calibration process

Before the calibration of thermoluminescent dosimeter reader, care was taken to select thermoluminescent discs which gave same readings and exposed all the thermoluminescent dosimeters to a known dose in Cobalt therapy machine. We had given a dose of 200cGy to all the discs. A Perspex sheet of thickness 5mm, which acts as tissue equivalent material, was used as build up material. The thermoluminescent dosimeter discs were then kept in a radiation free area for 24 hours and then all these discs were read with a thermoluminescent dosimeter reader. Those thermoluminescent dosimeters which gave same values were then batched together.

After annealing the chips, each batch was again exposed with 200cGy and see that reading was same within a given batch. Each batch was then used for calibration of thermoluminescent dosimeter reader.

Each batch of thermoluminescent discs after annihilation was again exposed to a known dose (eg 200cgy). After 24 hours in radiation free area the dose absorbed by each disc was measured using thermoluminescent dosimeter reader. The difference between the dose given and dose measured was noted. We have adjusted high voltage settings and the unit factor of the thermoluminescent dosimeter reader, to get the given dose, whenever there is a difference. The standard display of the 2800M Victoreen dosimeter is coulomb. Current generated by the photomultiplier tube in the reader is integrated over a given period of time. This current is calibrated for Grey. This calibration factor is unit factor of unit ρC/mR (micro coulomb/milliroentgen where roentgen is a unit of radiation exposure). It was usually supplied by the manufacturer. Unit factor depends on the thermoluminescent materials and energy of radiation. Once the adjustment is made, extreme care was exercised to see that it is not altered. For further accuracy a calibration curve was also used.

Calibration curve

Thermoluminescent discs in each batch were exposed to different known doses. Discs from same batch were exposed to radiation, in steps of known doses. Using the thermoluminescent dosimeter reader, the dose absorbed by the chips was measured. A plot between the known dose and the measured dose which is linear is shown in **Fig 8**. In the present investigations the known dose varied from 25cGy to 250cGy in 25cGy steps .This plot shown in fig 8 served as calibration graph for that particular batch of thermoluminescent dosimeters. This graph helps to evaluate the accurate dose when exposed to unknown doses. Each batch of thermoluminescent dosimeter disc has its own calibration.

Verification of the efficiency of half beam block

For most of the breast cancer treatments, we use half beam block. This reduces the dose to the lung and underlying heart. The half beam block is a lead block having a thickness of 5cm. This is fixed to the collimator of the therapy machine before the beginning of the treatment. This block cuts half of the beam and hence reduces dose to the lung and underlying heart. The efficiency of the block has to be checked before the treatment. The efficiency was checked by using dose profile. Dose profile is dose distribution in tissues or phantoms for radiation fields. It was measured at dose maximum region.

Dose profile verification was done using thermoluminescent discs. These discs were kept two centimeter apart from each other. The thermoluminescent dosimeters were placed along X-axis of the treatment couch at a distance of 80 cm(Source to Surface Distance, SSD) in Theratron 780 E and 100cm in Elite100.(SSD 100).These were kept in horizontal axis. A perspex sheet of thickness 0.5cm was kept over the discs for build up, where dose is found to be maxium.These were then exposed without half

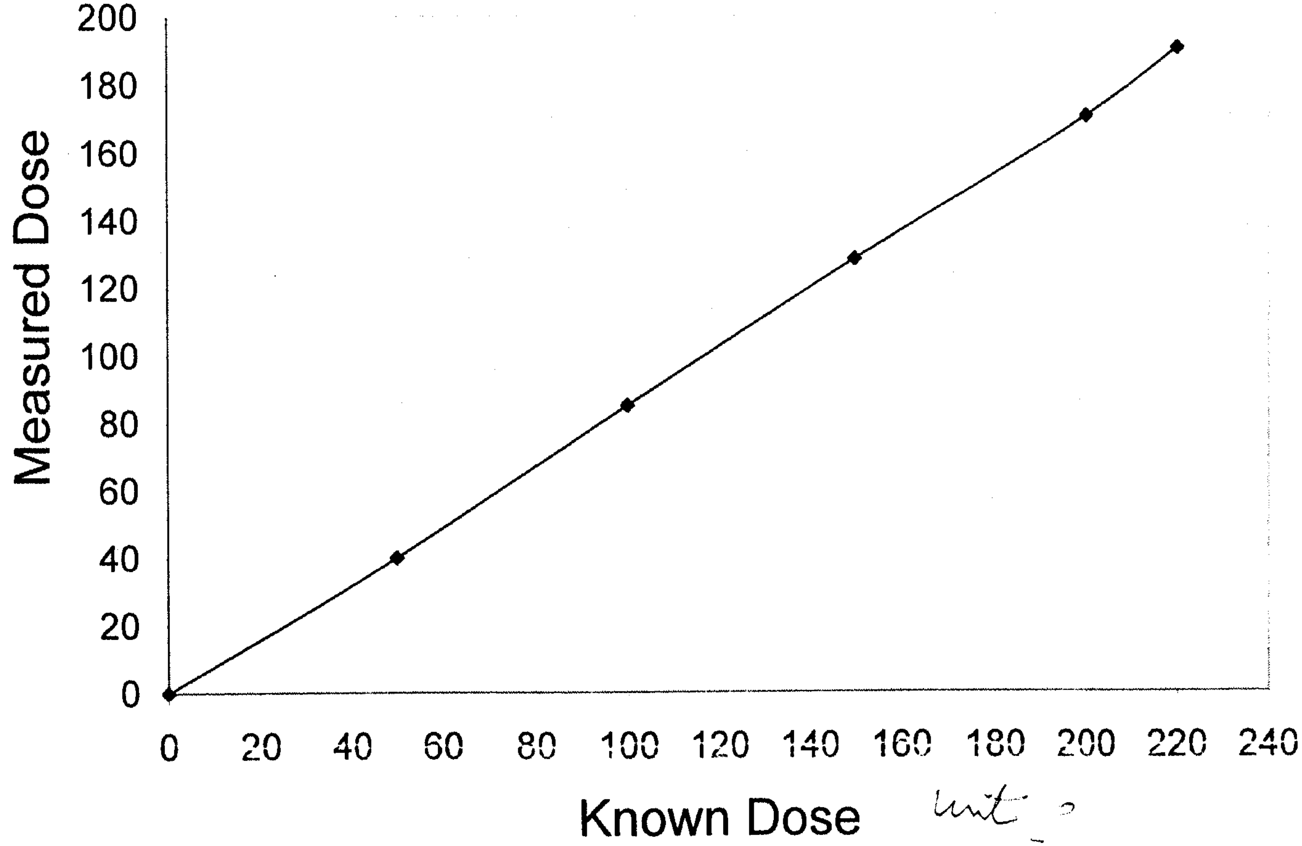


Figure 8 Charecteristic Curve

beam block (HBB) **(fig 9)**. With same set up another set of thermoluminescent dosimeters were exposed with half beam block. As the daily dose to breast cancer is usually is 200cGy, the exposure dose was also 200cGy.The dose absorbed in thermoluminescent dosimeters were measured on the next day and the profile drawn is shown in **figs 10, 11**. On verifying the profile the efficiency of the block was found out.

A sharp decrease in dose is noticed in the blocked region. The dose was however, not zero, as there was scattered radiation in that region.

The dose profile of a machine helps to check the performance of the machine. It was found, from the profile of the dose at the centre of the field, when half beam block was used, that there was no sharp decrease to a minimum value. This was due to the contribution by scattered radiation from the tissues irradiated and the block itself

Patient dose measurement

Dose measurement at different points was carried out in the case of carcinoma breast treatment. Dose at different points was found out using standard tables and isodose charts, treatment planning system and dosimeters. Treatment Planning System (TPS) and calculation methods give the amount of radiation dose present at different points on the breast. Dosimeters help to find the dose delivered at these points during treatment. A small change in setting up of patient in the treatment room affects dose delivery. To check for the consistency of dose delivery, evaluation of dose on day to day basis was also carried out. For this solid state detectors[43] and thermoluminescent dosimeters were used. Radiation dose at the entry point and exit point were measured in all cases everyday using these detectors. The dose variation with reference to the prescribed dose and the day to day variation in the individual patients was also studied. In the present investigations we had considered 80 patients with Carcinoma breast.

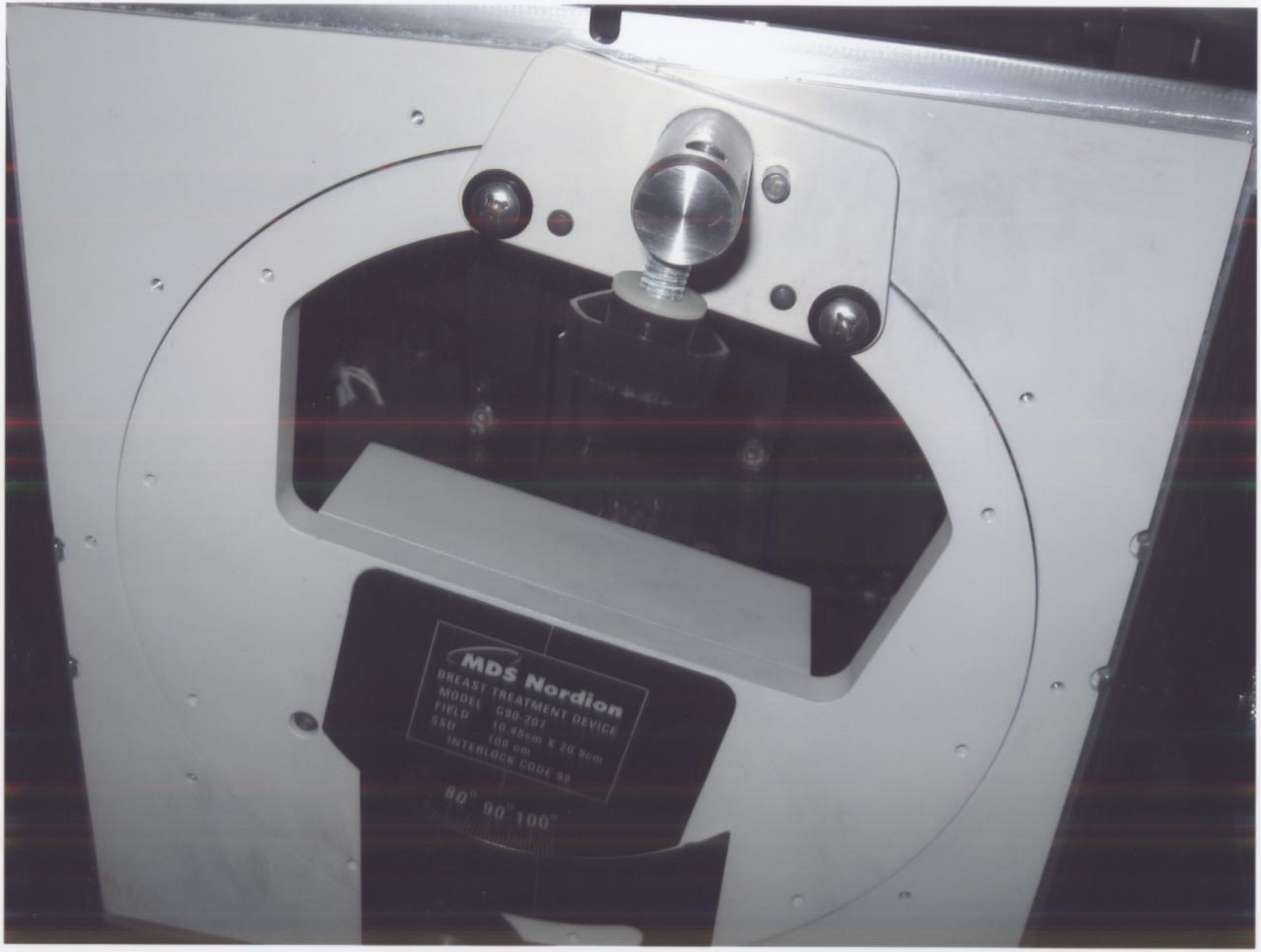


Figure 9 - Half Beam Block made up of lead. This helps to block half of the beam from cobalt machines to reduce dose to heart and lung

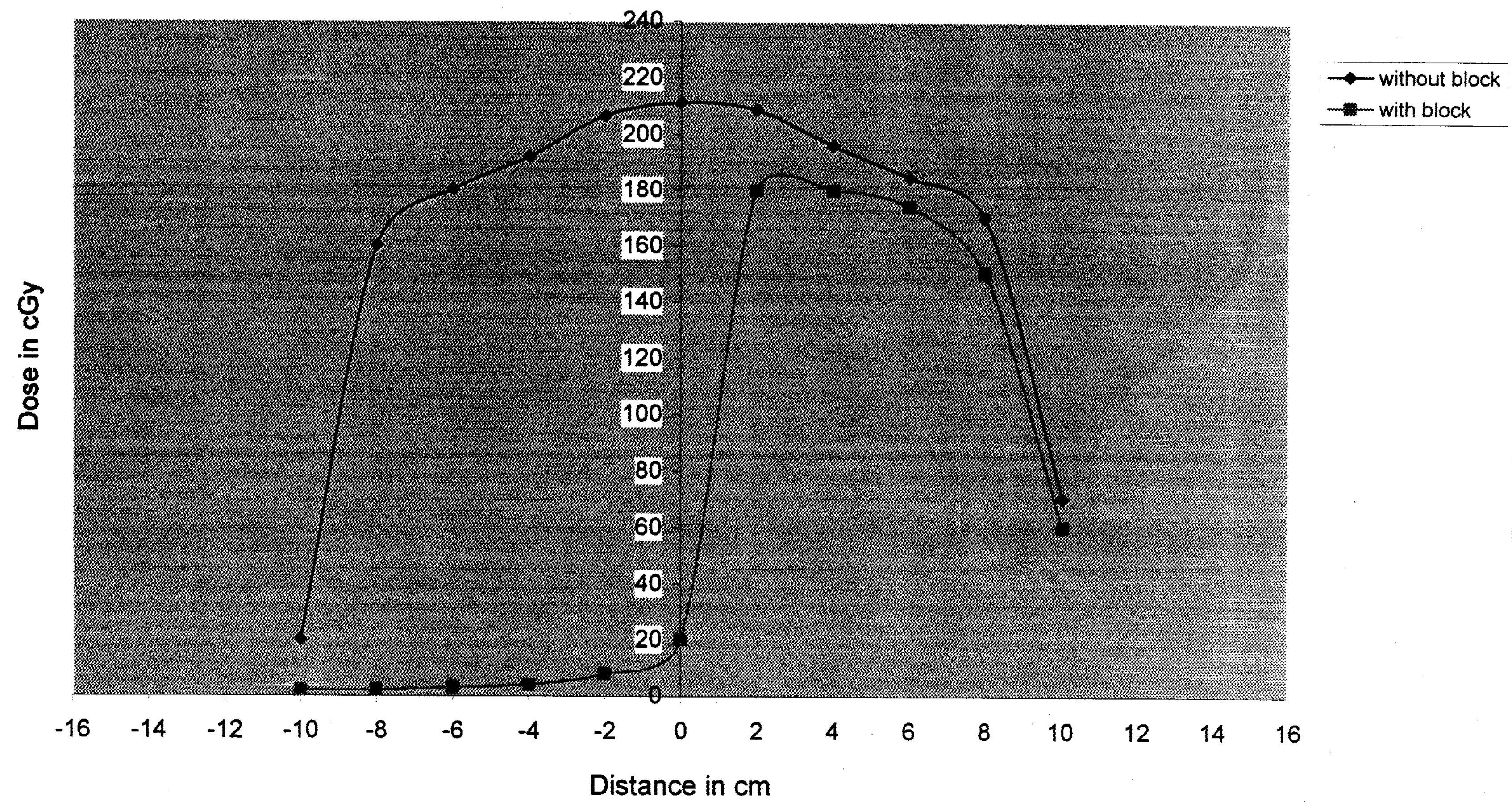


Figure 10 Theratron 780 E Dose distribution with and without half beam block

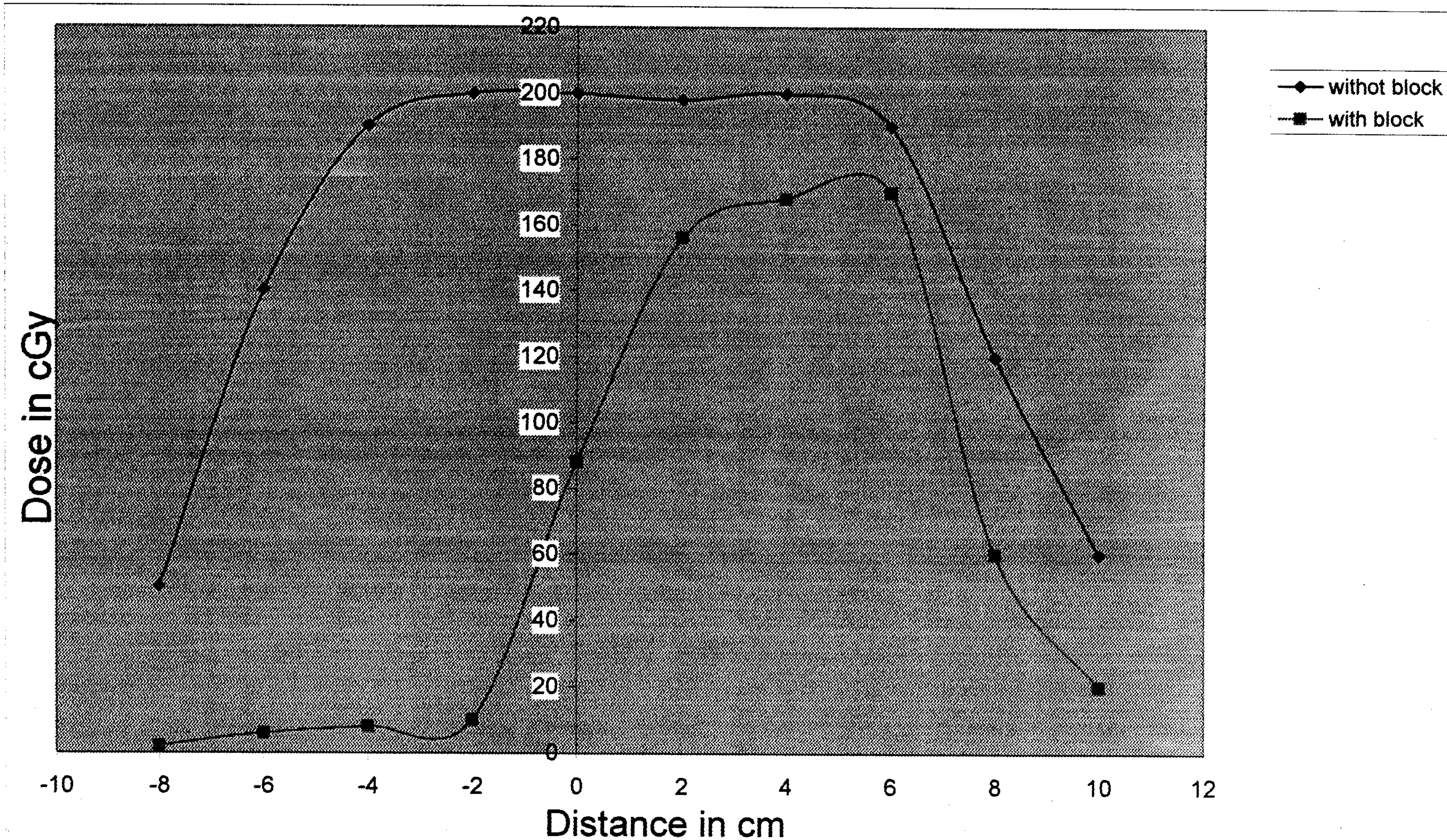


Figure11 Elite100 dose distribution with and without Half Beam Block

43 c

Day to day variation in the case of carcinoma breast

Day to day variation in the case of carcinoma breast was carried out using both Theratron 780E and Elite 100 machines. All the cases studied, were treated with four field technique. Out of the four fields, two were tangential fields, one was supraclavicular field, and the fourth one was posterior axillary field. The dose given through tangential field was 4000cGy in 20 equal intervals while in supraclavicular field it was 4500cGy in 20 equal intervals.

Solid state detector *'Isorad'* manufactured by Sun Nuclear Corporation, USA was used in the present investigations. This is shown in **fig 12**.In this detector internal build up is achieved through the use of different materials for energies from Co-60 to 25MV accelerator beams. Therefore an external build up is not necessary for the solid state detector. The detector is silicon diode detector. This detector when coupled with electrometer of Victoreen, model 37-720 made in USA **fig 13** gives high accuracy. This detector is highly advantageous because of its small size, ruggedness, immediate readout and simplicity of operation.

Solid state detectors give the instant reading while the thermoluminescent dosimeters have to be kept after exposure for 24 hours before the measurement. These thermoluminescent dosimeters and detectors were placed at the entry point of the tangential beam and centre of supraclavicular field. When solid state detector was used the dose at the points could be read out instantly using electro meter. In this case the solid state detector was placed at the point of entry in medial tangent radiation field and the dose in electrometer was recorded. Then the detector was placed at the entry point of the lateral field and the reading was recorded. As the diode detector and the electrometer were already calibrated, we could read the dose directly. Also solid state detector was positioned in the central point in the case of supraclavicular treatment and measurements were

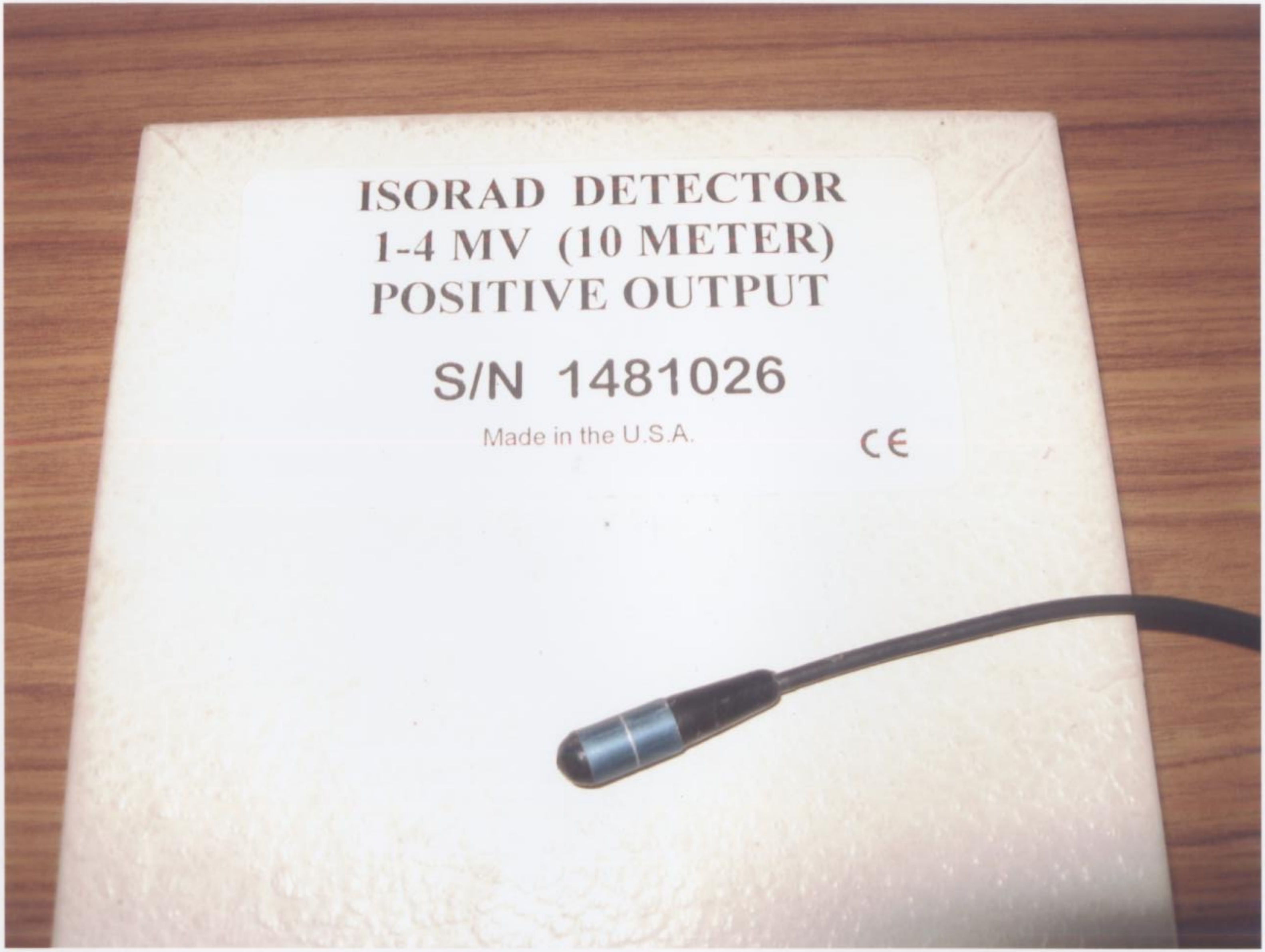


Figure 12 - Solid state detector 'Isorad' manufactured by Sun Nuclear Corporation, USA

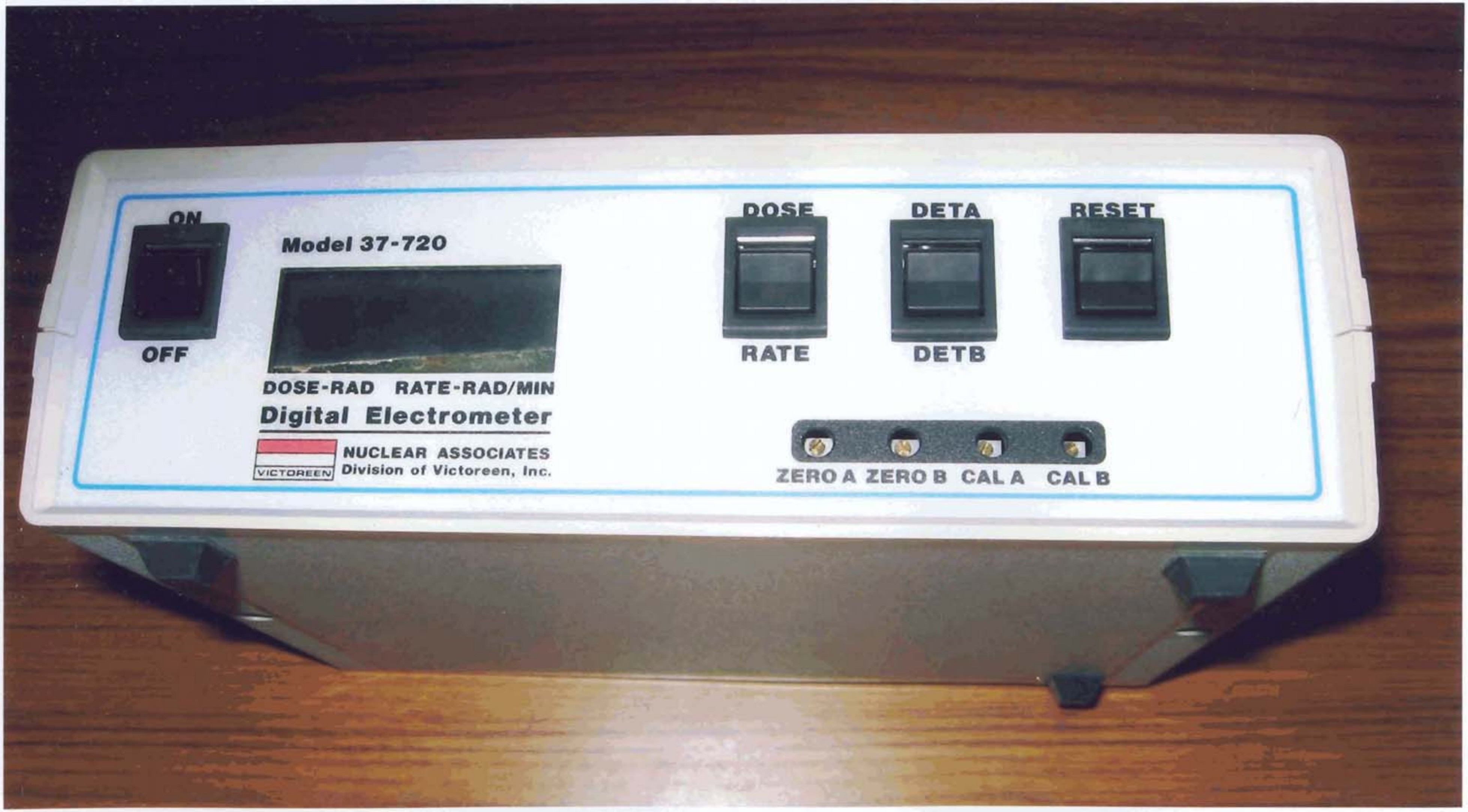


Figure 13 - Digital electrometer to read the dose absorbed by the dosimeters in cGy.

carried out at a source-surface distance of 80cms. The detector was exposed during the treatment. The treatment times varied from I to 2 minutes among patients. These measurements were repeated for 15 days for each patient. This procedure is carried out in 20 patients out of 80 cases studied.

In the case of thermoluminescent dosimeter discs, a build up was used for the measurement. These TLD discs were placed at the entry points of medial tangential field and lateral tangential field, every day. The exposed thermoluminescent dosimeters were readout the next day. This procedure was carried out in 10 patients. Day to day variations were recorded in both the techniques using solid state detector and TLD.

Dose on entrance, exit and nipple position of treated Breast – variation from calculated values from the measure values using cobalt therapy machines

Dose variations at different points were studied in 60 patients. There are generally two types of treatments. One is radical which is curable and the other is palliative which is given for pain relief. Radical cases are usually early stage carcinomas while palliative cases are carcinomas at an advanced stage. Patients were selected randomly without giving much consideration as to which breast is affected. Some of these cases were treated with theratron 780E and some in Elite 100 cobalt machines.

Dose was measured at entry point, exit point and nipple with both the cobalt machines.

Thermoluminescent dosimeters placed in a thin polythene packet were placed at the point of entry. The Source to surface distance was adjusted and the patient was positioned. The patient was in supine position and the hand was placed as shown in **fig 14**. Before the treatment was carried out, each patient was planned in the therapy machine itself. During the planning,

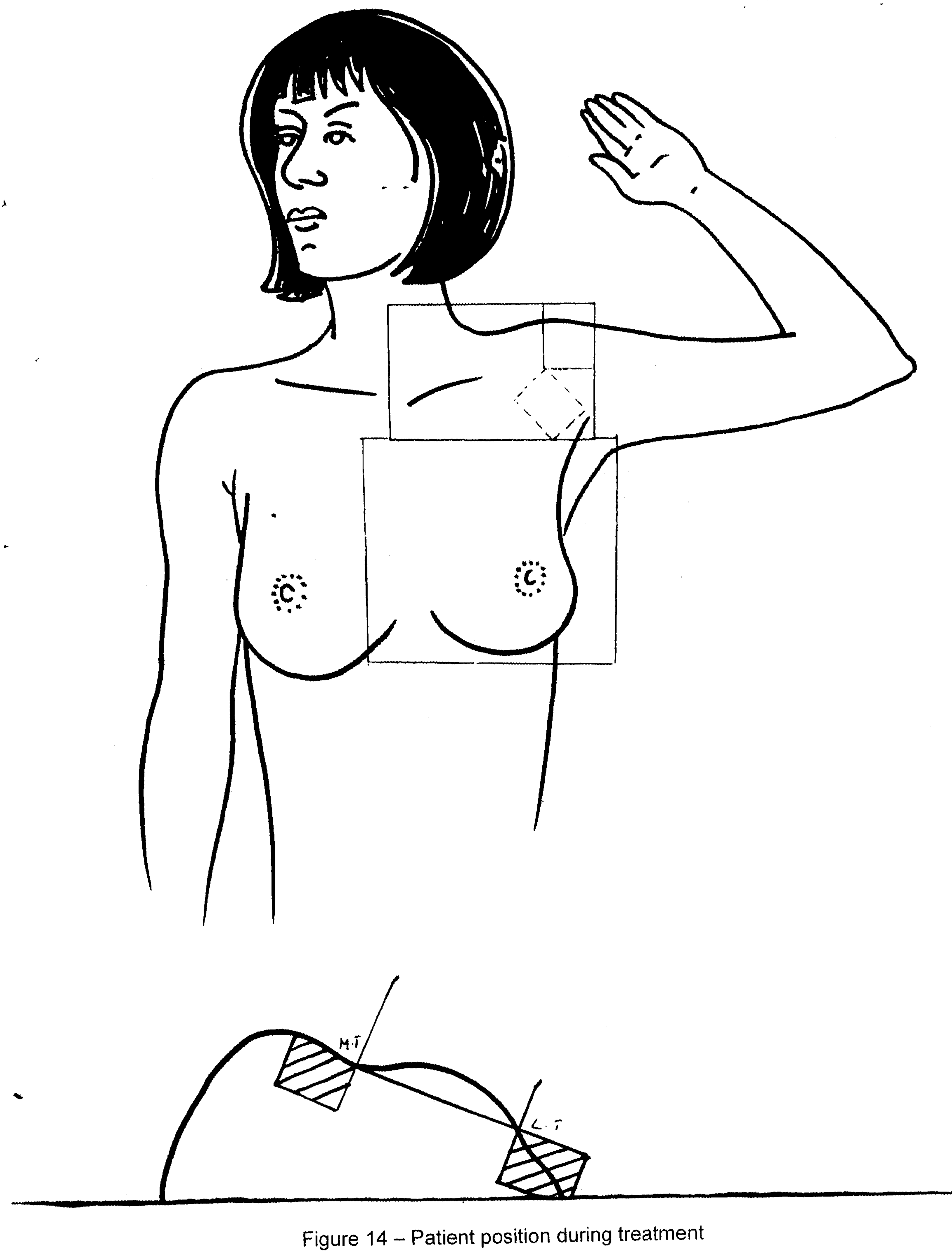


Figure 14 – Patient position during treatment

before giving radiation, treatment points of entry of medial tangent and lateral tangent fields were marked on the patient. The angle of gantry and collimator(field defining diaphragm) was decided to see that the field covered the maximum treatment volume.

A small Perspex sheet was used for build up in measuring dose at entry points. The dose at entry point was the total dose of entry plus exit dose. The exit dose was found out using the dose calculation method with percentage depth dose data [1]. Here the depth was taken as the interfiled distance. In the case of mastectomy, as the fields used were tangential fields, the separation of medial tangent field from lateral tangent field was taken as interfiled distance. The total dose at the mid point of the separation for the treatment was prescribed by oncologist. Two thermoluminescent dosimeters were kept in a polythene bag and placed at the nipple position during the treatment. As moisture from the body will affect the absorbed dose, TLDs were kept in polythene bags before placing them on the patient. These TLDs were taken out after the irradiation and kept in a radiation free area for 24 hours before any measurement is made. As these thermoluminescent dosimeters were already calibrated, the exact dose corresponding to the measured dose was found out from the calibration plot. The reading is in the unit of absorbed dose Grey (Gy).

The dose variation from both the cobalt machines was compared using TLDs in patients. The contours of the patients differ from one another. This affects the dose comparison for the two cobalt machines. Therefore a tissue equivalent wax phantom was used for the dose comparison. Here thermoluminescent dosimeters were used for the measurement.

Probability of occurrence of cancer to the contralateral breast (opposite breast of the treated breast) depends on the amount of dose absorbed by it during the radiotherapy. In the present study the dose to the contralateral breast was measured using thermoluminescent dosimeters. For this the thermoluminescent dosimeters were kept at four positions as shown in **fig 15** during the treatment and doses were measured.

Dosimetry with Accelerator beam

Dosimetric work was also carried out with linear accelerator. Amrita Institute of Medical Sciences (AIMS), Kochin, is having two linear accelerators with electron and photon beams. The accelerator 'Elekta Precise' at AIMS was used in our investigations. This machine gives high energy X-rays and electron beams. The energies of electron beams are 4MeV, 8MeV, 10MeV, 12MeV and 15MeV and the photon energies are 4MV, 6MV and 15MV. The output consistency was checked daily from these accelerators. The machine also has the facility to give conformal radiotherapy, Intensity Modulated Radiotherapy, wedge treatment and electron therapy. Collimator has multi leaves which are necessary for conformal radiotherapy and Intensity Modulated Radiotherapy. Different shapes of fields according to tumour volume were given for the treatment. There are 40 multi leaves in the machines. The maximum field size of collimator is 40cm x 40cm and the width of each leaf is 1cm. In cobalt machines such as Theratron 780E and Elite 100, four diaphragms are there to define the field size. These diaphragms can be moved in parallel. Different shapes, if necessary, can be achieved using additional lead blocks. However, there is a limitation of the cobalt machines at our institution as there are no multileaves facilities.

Each leaf can be controlled separately and this helps to give conformal radiotherapy. In the accelerator 'Elekta Precise', the wedges are motorized. In the case of cobalt therapy machines conventional wedges with fixed angles are used. These are additional accessories of therapy machines which have to be bought separately. These are attached separately to the collimator whenever it is necessary. However in Eleka Precise, any wedge angle can be chosen as it is an integral part of the machine. The wedge is

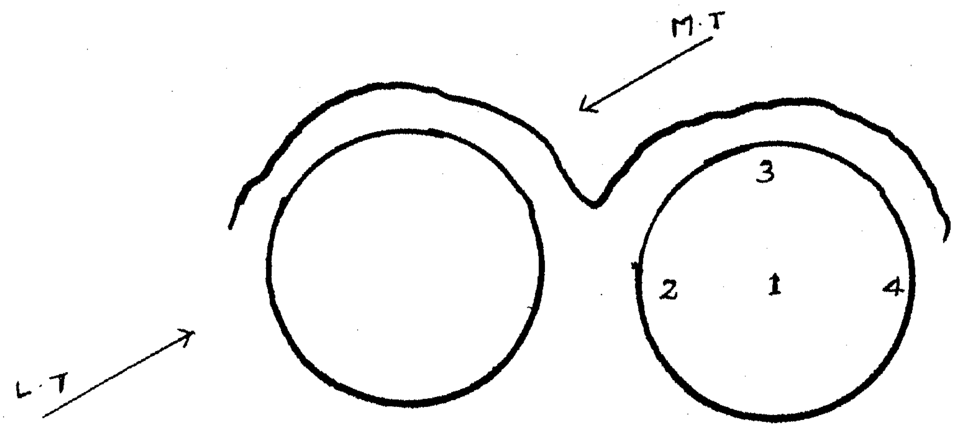


Figure 15 – Dose in different points in Contra Lateral Breast

above the multi leaf collimator. The geometry of the breast and sensitive organs nearby makes it necessary to use different shapes of fields. The multi leaves help to achieve any shape of fields. In addition, Breast dosemetry study was also done after irradiation using Elekta and a schematic diagram is given in **fig 16.** Elekta Precise is a digital accelerator. It has a drum roller mounted gantry which is isocentric, traveling wave guide and a magnetron. The magnetron is a device that produces microwaves which functions as a high power oscillator. This along with the wave guide helps to accelerate the electron produced in the cathode of accelerator.

Different cases are treated by different methods using two Elekta Precise machines of AIMS. The treatment method was dependent on the stage of the diseases, nodal involvement, type of the surgery and the shape of the contour of the patient.

In the present investigations with Elekta Precise, all the cases were first planned in C.T simulator, which simulates the machines. In C.T simulator, computed tomography scan was taken with markers to identify the area, point of entry, and other reference points about which the planning is done. These cases were then planned in treatment planning system with the help of computed tomography scan. The planning system used was Xio 3D treatment planning system, made in USA. Clarkson algorithm [61] was used for measurement of dose. On the CT image of the patient, the contours of the patient body, target volume and other organs at risks were marked. With the help of 3D Xio panning system the treatment parameters like field size, gantry angle, collimator angle and wedge angle were decided. Also the technique as suggested by treatment planning system to give high dose to the tumour and low dose to other organs was employed. These planned cases were sent to the treatment machines where they were set up accordingly. All the cases were verified once in a week by taking portal images. Portal images were taken to monitor patient set up relative to the radiation portal, before the treatment was carried out with the machine.

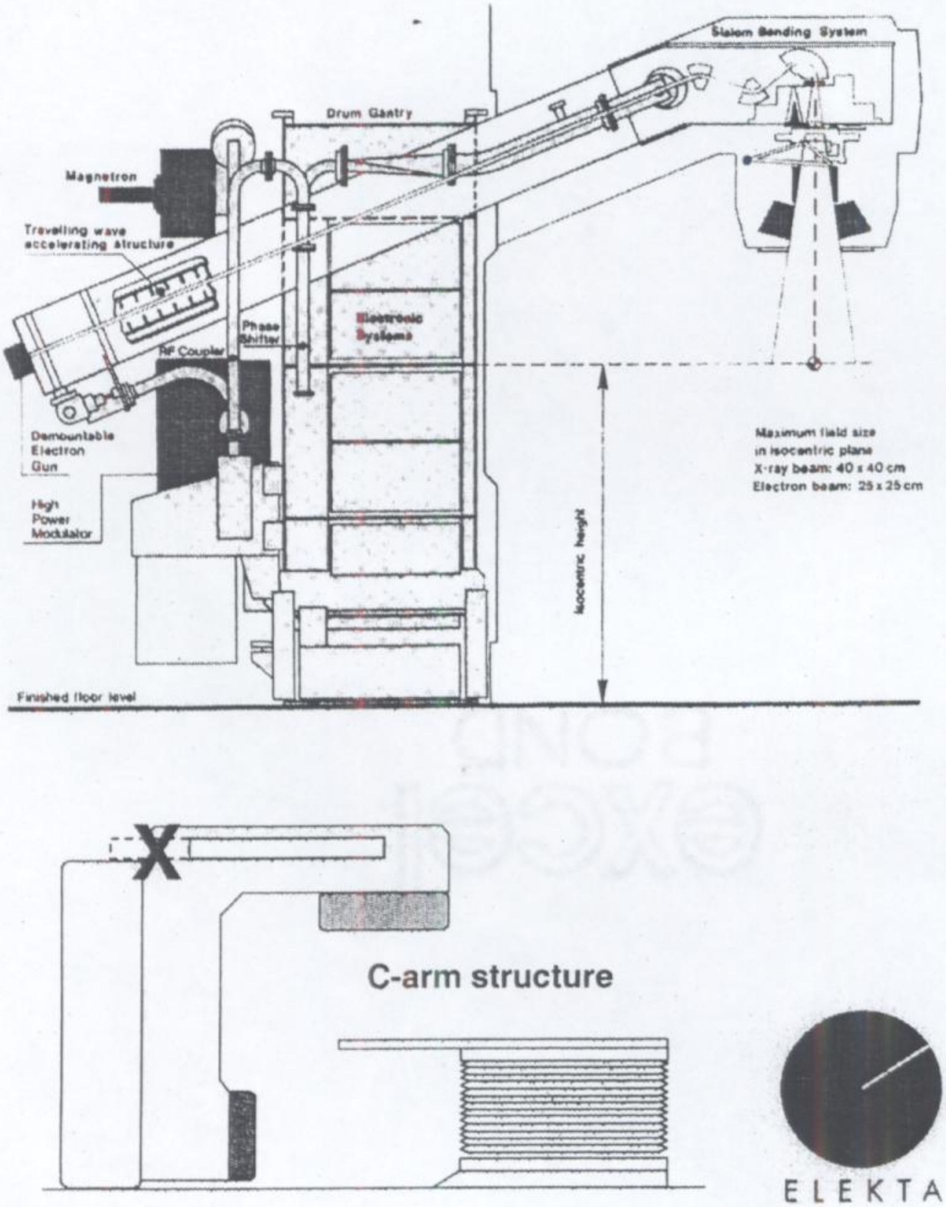


Figure 16 – Schematic diagram of Elekta Precise Accelerator

These relatively poor contrast images were then compared with computed tomography images to verify the set up position of the patient in the machine. To take portal film, especially with accelerators having image facility, a few cGy of radiation was given to the patient which produces the image.

Most of the mastectomy cases were treated with electron beam from Elekta Precise. If nodes were involved additional photon beams were used. A photon beam of energy 6MV was used for this treatment.

Eight cases were studied in the present work of which three were mastectomy cases and five were conservative cases. The treatments of these cases were different depending on the treatment volume and the nodal involvement. If supraclavicular fossa and axilla were to be irradiated an isocentric technique with photon beam was used. Wedges were used to get a uniform dose distribution in intact breast. Breast board and immobilization techniques were used for positioning the patient. This helped to reproduce the positions of patients every day.

Treatment of chest wall, whole breast and nodal involvement necessitated careful treatment planning to avoid excessive irradiation of normal tissue which encompassing the areas at risk without over lap.

Three field single isocentric technique, combination of electron – photon beam technique and chest wall irradiation with electron beam technique were used in the present investigations.

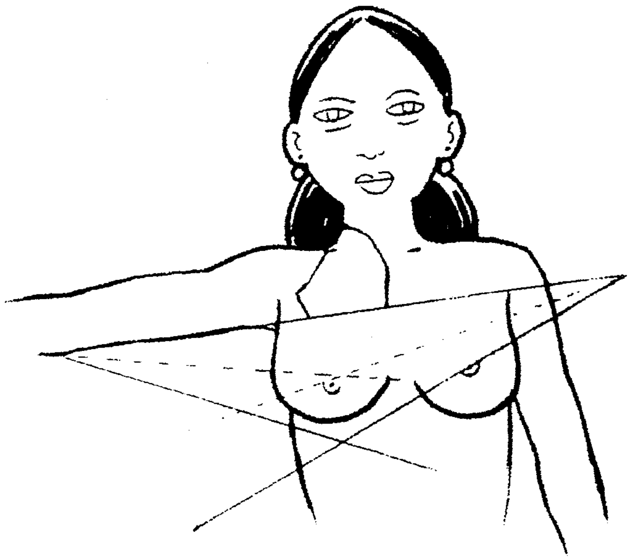
Techniques

Three field -single isocentric Techniques

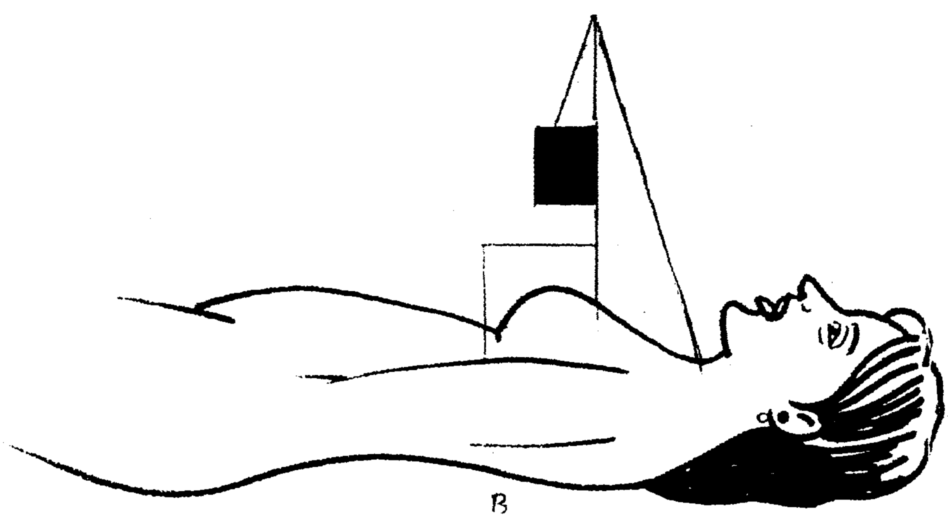
This technique helps to achieve an ideal match between the lower edge of an anterior supraclavicular and the superior edge of the two opposed tangential fields. The Supraclavicular Fossa is usually treated with a half beam technique to achieve a non-divergent edge at the lower part of the field. Couch rotation, collimator angle and breast board were used on tangential fields to match with the lower part of the supraclavicular field. In this method, three fields were used with a single isocentre as shown in **fig 17,18.**

To achieve this three field -single isocentre technique breast board and multi leaf collimators were used. Patient was laid on the treatment couch in supine position with arms above the head. A match plane was defined by setting the central axis along the line between tangents and Supraclavicular Field. This is the upper border. The mid- line was set at the medial border of the chest wall field. Using the table top ruler and table distance indicator, the distance between the match plane and lower border of the breast and chest wall was measured. This is the treatment length of the tangential field. Then central axis was moved half way between the upper and lower borders. This is the centre line of the tangential field. Then the points where this line cross the medial and lateral borders, is marked as entry point of tangent tangential field. About this point the gantry is rotated until the medial and lateral line cross over the central axis line. The angle of gantry was noted. The separation between medial tangent and lateral tangent entrance point was measured. The depth of the isocentre of the accelerator machine, in the patient, was taken as the mid point of the field separation. Then the depth at half the separation was set by moving the table up and towards the gantry. Finally to set the isocentre, we moved the table longitudinally out, so that the central axis was again at the level of the supraclavicular match plane. This is the isocentre for the treatment. Using asymmetric collimator, each half of the field was blocked while treating the other half. A posterior axillary boost was also given in this Three field -single isocentre technique.

Wedges were also used with tangential fields. Tangential fields of 6MV photons with wedges were used for treatment. These are used in Breast



A



B

Figure 17 –. Three field isocentric method

A) Interior angulations of the tangential beams eliminates their divergence into the supraclavicular field.

B) Splitting the supraclavicular beam eliminates it divergence down into the tangential field

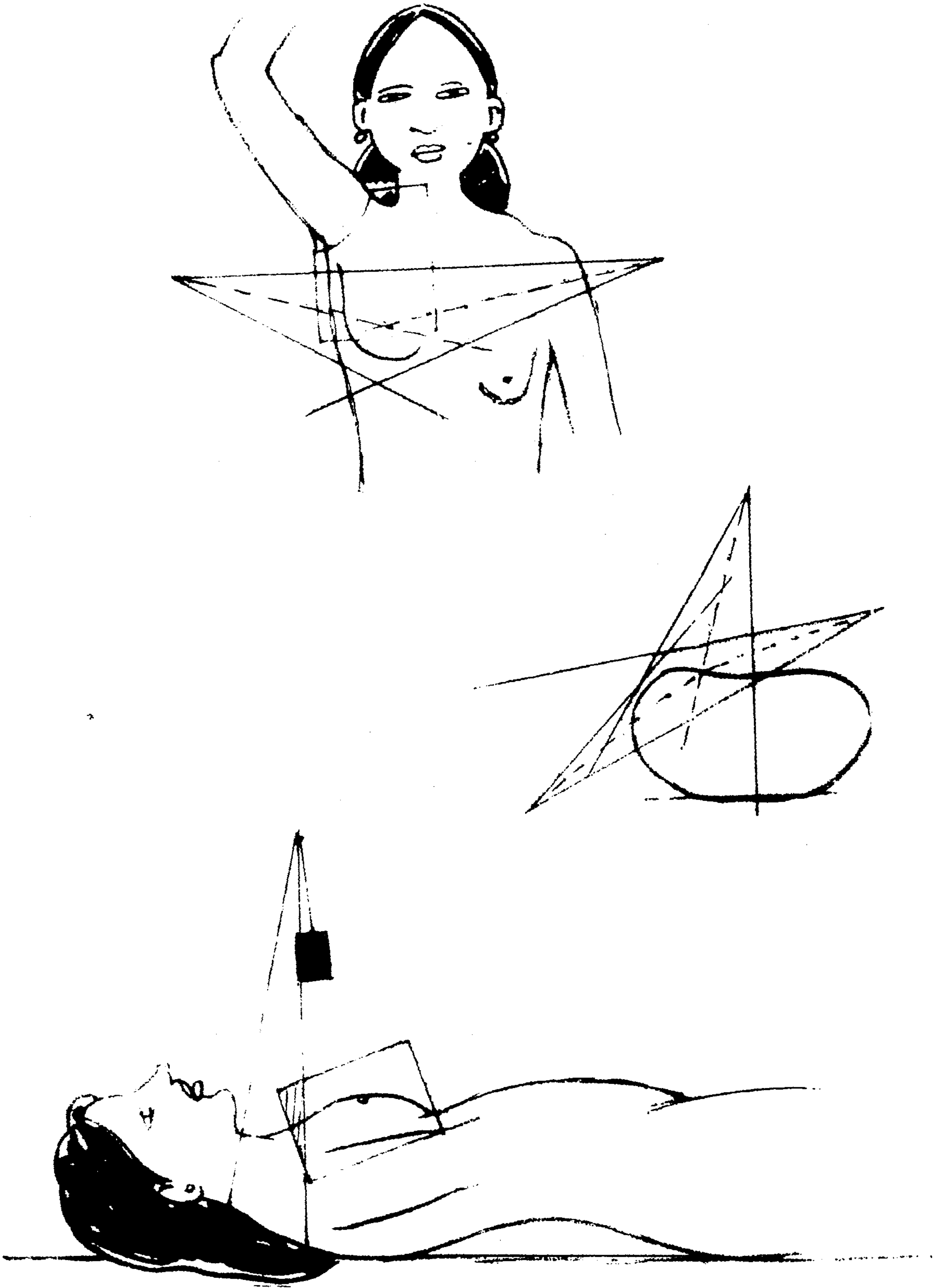


Figure 18 – Three field isocentric method

C) Three-field treatment beam geometry in irradiation of the intact breast and supraclavicular fields illustrated in coronal, cross-sectional, and sagittal projections. The supraclavicular and tangential field blocks are shaded.

Conservative Surgery radiotherapy. The motorized wedges available in the machine were used to get any angle of wedge suitable to get the desired dose distribution. The lower half of the tangential field was cut by multi leaf collimators.

Combination of Electron –Photon technique

This technique used matched photon and electron fields to treat the chest wall and nodal regions. In this technique an anterior photon field (6mV) extending from lower neck to the lower lateral chest wall was used to treat the Supraclavicular Fossa and axillary nodes together with the lateral chest wall. The field centre was placed on the medial border of the chest wall field and was carefully matched to the field of electron beam to chest wall. The field of electron beam was marked using custom blocks. These blocks were made by an alloy called cerrobend which cuts off the unnecessary radiation beam and helps to irradiate the chest wall with desired shaped fields. The anterior electron beam treats the chest wall and the internal mammary field if required. The electron energy is chosen from 3D treatment plan to give uniform dose. In these two studies 85% isodose is chosen as prescribed dose which gives uniform distribution to the required volume. This helps to reduce the lung dose while giving prescribed dose to depth. The dose distribution obtained in the CT cross section of infected breast at nipple position, using this method is shown in **fig 19**.

Electron beam Technique

Electron beam is given from anterior part to the chest wall after mastectomy. The beam energy was decided according to the depth to be treated (2-3cm volume of lung was included, in all cases, other wise the tumour may be missed during the treatment, because of breathing.) According to the isodose value which covers the treatment volume the dose was prescribed so as to get uniform distribution throughout the volume.

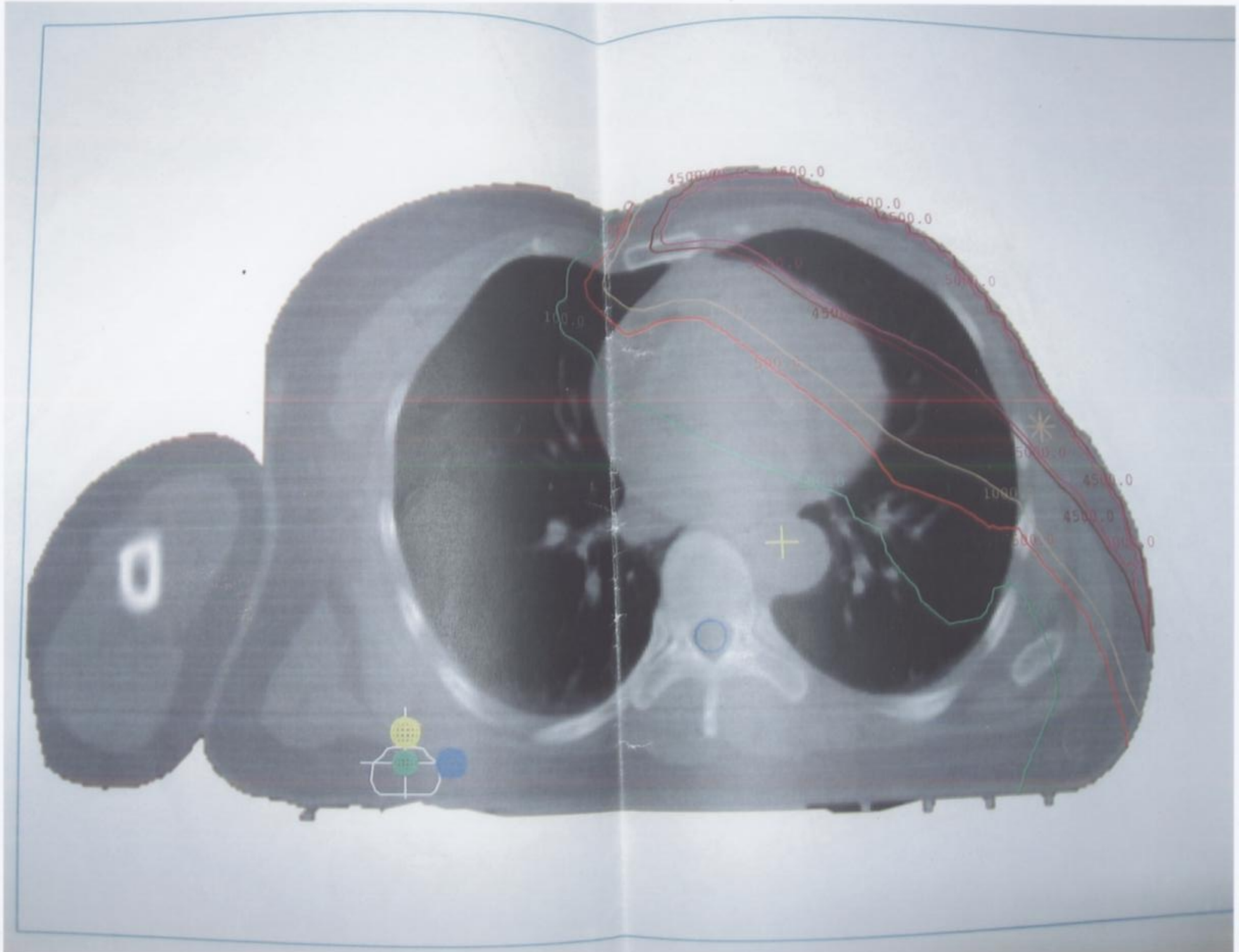


Figure 19- Isodose distribution in the CT cut of chest wall of a patient treated with electron beam and 6MV photon beam from the Linear accelerator-'Electa

Electron beams fields and irregular fields are usually accomplished by using shielding, with the use of thin lead or low melting alloys, called custom blocks. This was placed in between the source head and patient lying on the treatment couch. The area of electron beam projected on the patient through the cut in the custom bloc was marked. This is the treatment area. This block was used during the treatment for the patient. Dose distribution is shown in **fig 20**

For the investigations carried out at AIMS, Kochi, dosimetry was carried out using Calsium sulphate with dysprosium doped ($CaSO_4$: Dy) thermoluminescent chips as well as Xio,- 3D treatment planning system. Eight cases were studied with accelerator Elekta Precise. In three of them, the chest wall was treated by electron beam and nodes by photon beam. In 5 others 6MV photon beam was used for the irradiation of affected breast. All these cases were studied with 3D Xio treatment planning system also.

In the three cases out of eight, where chest wall was treated by electron beam, Supraclavicular Fossa and axilla were treated by 6MV photons. The treatment planning was done in such a way that the whole treatment volume got uniform dose. Electron beam of energy 8MeV was used for the treatment. The choice of energy depends on the depth up to which the dose has to be given. As the depth from the surface increases, in the case of electron beam, the dose decreases rapidly and accordingly only a small volume of lung gets radiation. When the patient breaths during the treatment the chest wall moves up and down. Therefore there is a possibility to miss the tumor during the treatment unless a 2cm depth of lung from the chest wall is not included in the treatment volume.

Eight breast cancer cases studied at Amrita Institute of Medical Sciences were treated using linear accelerator facility there. Five out of eight cases studied were Breast Conservative Surgery cases. Each case was treated with a different technique, which depended upon the stage and site of

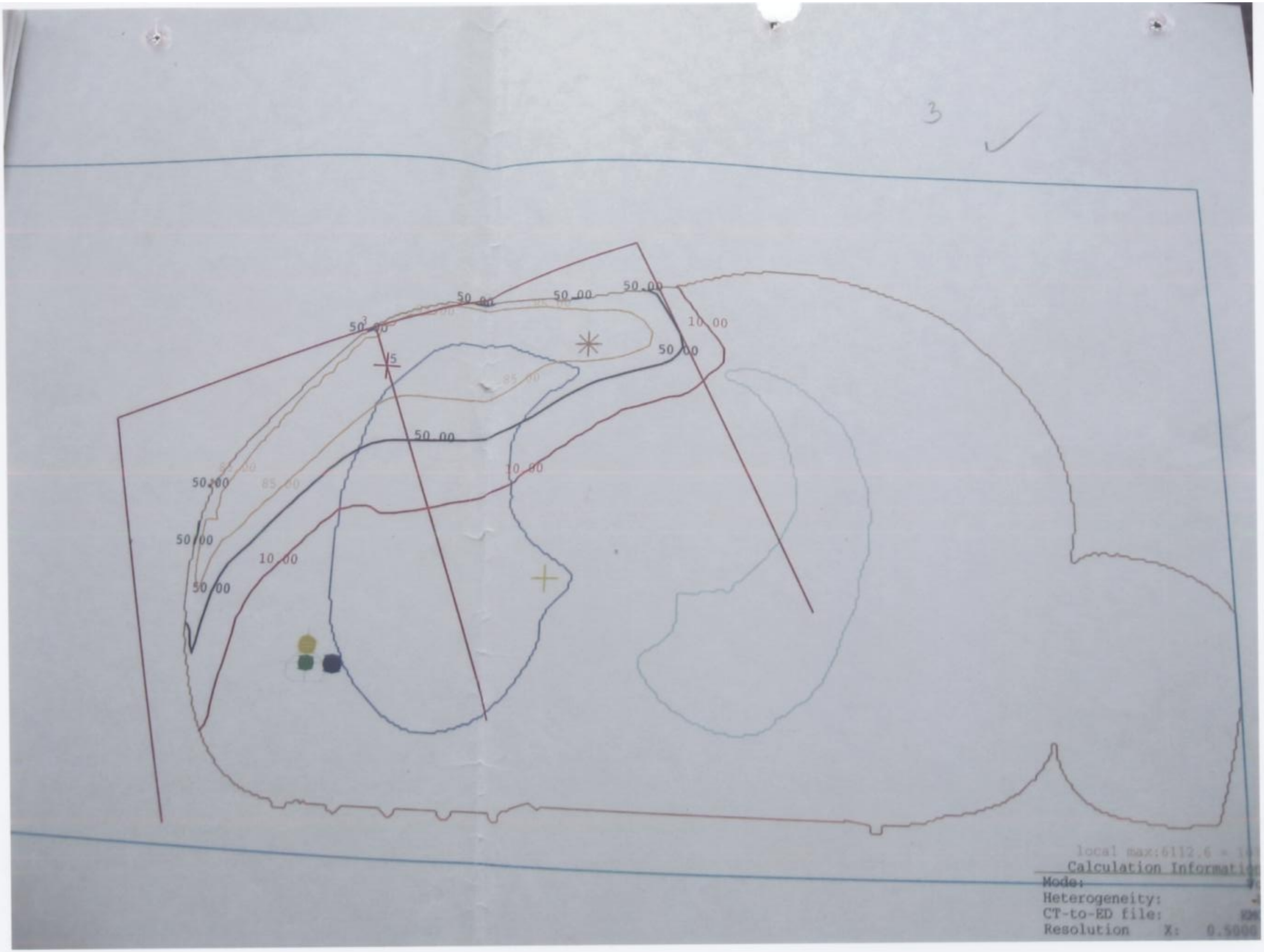


Figure 20 - Isodose distribution in the CT cut of chest wall of a patient treated with electron beam alone from the Linear accelerator-'Electa"

the tumour. All breast cases were treated with radiation field using wedges. The details of the methods of approach are as follows:

One of the cases was treated with a wedge of angle 20^0. (In accelerator "*Elekta Precise*", any wedge angle can be selected unlike cobalt machines where standard wedges with constant angles are used.) The field size of the tangential fields was 12cmX12cm. In addition to this tangential field a booster dose was given with a wedge of angle 30^0 through a field of 3cmx4cm. The booster dose was 1000cGy (10Gy) in 25 equal intervals while dose through the larger fields were 45Gy in 25 fractions. Therefore smaller part of the target volume got 55Gy while larger volume got 45Gy. The booster dose was to give additional dose wherever it was found necessary to give more radiation for better results.

The second case was treated with 25° wedge tangential field with a dose of 30Gy in 10 fractions. A booster dose of 1500cGy in 5 fractions was given with 12MeV electron beam.

The third case was treated with two tangential fields using 25° wedge and a dose of 45Gy was given in 25 fractions. One supraclavicular anterior posterior field was also used where the dose was 36Gy in 20 fractions. Axilla was treated with posterior anterior field with 1800cGy in 5 fractions. A booster dose ~~with~~ was also given to the chest wall with 4MV photon beams using tangential pair and 45 and 35 degree wedges (45 for Medial field 35 for lateral field respectively). The dose given was 1428cGy in 7 fractions.

In the fourth case, the breast was treated with 5 fields. Two tangential fields were used to give 45Gy in 25 fractions using 12° wedge. A booster dose was also given through tangential fields with 35° wedge and the dose given was 1276cGy in 25 fractions. 15Mev electron beam was used to give another booster dose of 1250cGy in 25 fractions.

The fifth patient, studied, was treated with 6MV photon beams. The tangential field was given with wedges of 25° angles and the dose was 45Gy in 25 fractions. Supraclavicular fossa and axilla were also treated with 6MV photons with a total dose of 3600cGy and 900cGy respectively.

In the case of photon beam treatment the thermoluminescent dosimeter measurement was taken for tangential beams. The thermoluminescent dosimeters were placed at the medical tangent positions, lateral tangent positions and nipple positions.

Three out of eight cases were treated with electron beam. These cases were mastectomy cases. The chest wall was treated with on field electron beam with custom blocks to reduce the dose to the lung. In the case of electron beam, the measurement was carried out at one point only as the single field electron beam gives uniform dose in the chest wall. The dose to the contralateral breast of photon beam treatment was also measured.

Comparison of dose measured with Cobalt machine and Linear accelerator

Data of three cases treated with cobalt machines Theratron 780E and Elite 100 were compared with the data of 3D treatment planning system at AIMS, Kochi. Computer tomography images of these cases were taken with lead markers (lead markers produce artifacts, it can be avoided by using copper wires). For studying the plan in Xio 3D treatment planning system the CT images were transferred in a format compatible to the planning system Xio. The treatment parameters and treatment machine details available with the Xio 3D system were those of accelerators. The gamma rays from cobalt source and X-rays produced from 4 MV accelerators have similar properties. The Xio system has similar parameters of 4MV accelerator and therefore the CT images of the three patients could be planned in this Xio 3D planning system and the dose could be studied at different points. The only parameter

What is the basis for this assumption

of cobalt beam that is different from 4MV X-rays in addition to mono energy of cobalt beam is the depth of dose maximum point. In 4MV photon the maximum dose point is at a depth of 1.2cm from the surface of patient body where as it is 0.5cm for cobalt machines.

Dose at different points, dose distribution and dose volume histograms of these patients were studied [62] using the 3D system. The dose measured at some of the points like Medial tangent, Lateral tangent, Nipple points and contralateral breast with thermoluminescent discs were compared with the dose measured using the Xio 3D system. These doses were then compared with 2D Theraplan treatment planning system (TPS) at Medical College, Calicut.

The TPS uses dose data of points distributed in the field at different depths. 4MV PDD values themselves are different from those of ^{60}Co, and introduce large errors when dose measurements are compared with TLD. When one is interested in precise measurements this exercise is a waste!

RESULTS AND DISCUSSIONS

Sushama.P "Study of dosimetry in various cases in Radiotherapy" Thesis.
Department of Physics, University of Calicut, 2007

CHAPTER - 3

RESULTS AND DISCUSSIONS

RESULTS AND DISCUSSIONS

The dose measurements were carried at different points of breast affected by cancer, contralateral breast, lung and heart, using thermoluminescent discs, diode detectors and treatment planning systems following the procedures as given in chapter 2. The points of interest were entry point of radiation field, exit point of the field and nipple point in both contralateral breast and cancer affected breast. In the case of radical mastectomy, the points in the affected region were on the chest wall and in the case of breast conservative therapy these points were on intact breast.

Some of the dose measurements were carried out with cobalt machines and some with linear accelerator machine at AIMS. A comparison of these measurements was also done.

Dose measurements with cobalt machines

Dose variation at different positions like entry points, and nipple of treated breast using cobalt beams:

Table1 shows the variations of the dose measured at medial tangent entry position and lateral tangent entry position together with calculated values. The dose at entry points is the total dose due to entrance field and exit field which is measured using thermoluminescent dosimeters. The dose calculated for treatment is only the entrance dose. The total dose at the entry point was calculated using data of percentage depth dose. This data depends on the field size and interfiled separation. The second column of **Table 1** gives this total dose. The variation of dose measured from calculated dose is found to be from 2 to 25% in the case of both medial tangent and lateral tangent. In most of the cases the variation is between 10 to 20 percentages.

TABLE - 1

% of Variation = D-dn/Dx100

Where n=1 to 2

Dose calculated (cGy)			Dose at M.T cGy		Dose aT L.T cGy	
Sl. No.	Dose at D max	Dose (D) exit + entrance	Dose d1	% of variation	Dose d2	% of variation
1.	166	209	181	14%	180	14
2.	181	230	262	-14%	225	2
3.	263	317	360	-14	360	-14
4.	184	256	258	5	269	-5
5.	168	218	178	16	179	15.5
7.	173	215	160	25	180	16
8.	149	220	172.5	13.5	175	12.5
9.	167	199	195	11	210	4.5
10.	154	233	179	10	197	1
11.	185	244	225	3.4	235	2
12.	198	196	223	8.6	230	3.7
13.	147	240	220	12	196	8
14.	195	217	228	-5	201	16
15.	164	230	180	17	180	17
16.	190	283	225	8	280	18
17.	176	225	204	10	175	22
18.	144	193	171	11	169	12

Dose variation at Medial Tangent and Lateral Tangent positions

The dose variation from two cobalt machines is also compared and is given in **Table 2**. In Theratron780E machine the percentage of variation of dose in medial tangent is from 0.8-16%. In lateral tangent region it is 2-10%. In Elite 100, the percentage of variation in the case of Medial Tangent is 4.5%-13%, and Lateral Tangent, it is 22%

It can be seen that the percentage of variation of measured dose with calculated dose, in both the machines is high. In Elite 100, the variation is less in Medial Tangent region, but high in Lateral Tangent region where as in Theratron780E the variation is high in Medial Tangent region for most of the cases and less in Lateral Tangent region. In general the variation is less in Medial Tangent region, in the cases, treated with Elite 100.

Table 3 gives the dose differences at the points of entry with and without build up. Build up is the region where dose maximum exists, as shown in **fig 21**. To achieve build up as already mentioned, a small Perspex sheet of thickness 0.5cm was used, in such a way that it does not make any difference to the dose to the tumour. The Perspex sheet was placed over the thermoluminescent discs such that these discs were at the region of dose maximum. The present study shows that the dose absorbed by the thermoluminescent disc increased slightly with build up. Though the increase in dose is not much significant, we have conducted the study with build up. As the calculations were done at the maximum point, we had to use buildup method to maximize the dose for proper comparison.

Solid state detector, **Isorad,** was also used to find the dose at entry points of tangential fields and at the central position of the supra clavicular fields. **Table 4** gives the variation of the dose between the dose at entry points of tangential fields and calculated dose. The dose varies from 1.2% to 10%. In the **Table 5** the variation of dose in the supraclavicular region from calculated dose is given. The variation is from .9% to 3.7%

TABLE – 2 [Dose Variation in two Machines]

Sl. No.	Theratron		Elite	
	Variation M.T (%)	Variation L.T (%)	Variation M.T (%)	Variation L.T (%)
1	14	2	5	16
2.	14	14	8	18
3.	0.8	5	13	20
4.	16	15.5	10	22
5.	11	12.5	11	12
6.	8.6	5.7	4.5	17
7.	12	8	9	16

60.A

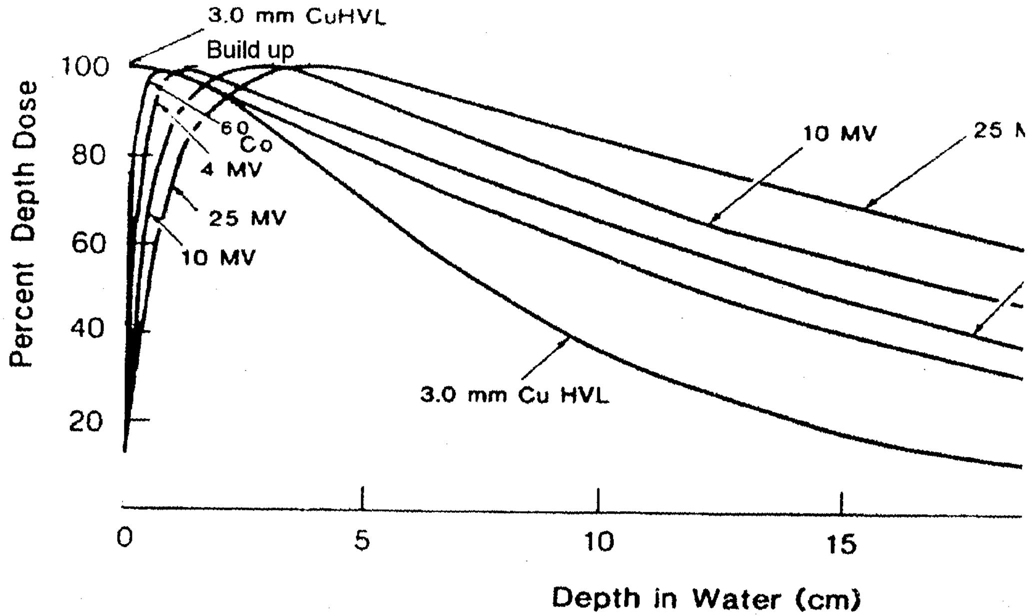


Figure 21 – Build up in water with Beams of different energies

TABLE – 3 [Difference in dose with & without build up]

	With build up				Without buildup			
Sl. No.	Medial Tangent (M.T)		Lateral Tangent (LT)		Medial Tangent (MT)		Lateral Tangent (LT)	
	Calculated Dose	Measured Dose	Calculated Dose	Measured Dose	Calculated Dose	Measured Dose	Calculated Dose	Measured Dose
1.	317	354	317	327	317	208	317	276
2.	199	163.5	199	200	199	200	199	190
3.	244	220	244	238	244	230	244	215
4.	240	230	240	220	240	228	240	201
5.	217	230	217	180	217	120	217	300
6.	236	255	236	280	236	250	236	210

This does not convey any meaningful [illegible]

[illegible]

TABLE - 4

Name	Measured dose	Prescribed dose	Percentage of Variation
Patient 1	231.7	212	−9.3%
Patient 2	197	186	− 4.8%
Patient 3	159	161	+ 1.2%
Patient 4	198.4	183	− 8.4%
Patient 5	178	173	− 2.9%
Patient 6	184.6	176	−4.9%
Patient 7	171.4	163	− 5.2%
Patient 8	201.5	183	−10.1%
Patient 9	195	180	− 8%
Patient 10	179.5	173	− 3.8%

Variation of measured dose with prescribed dose in the case of tangential field

Is this variation [illegible]

TABLE - 5

Name	Measured dose	Prescribed dose	Percentage of Variation
Patient 1	216.7	225	+ 3.7%
Patient 2	220.75	225	+ 1.9%
Patient 3	218.9	225	+ 2.7%
Patient 4	217	225	+ 3.6%
Patient 5	223	225	+ 0.9%
Patient 6	220	225	+ 2.2%
Patient 7	228.5	225	− 1.6%
Patient 8	220.5	225	+ 2%
Patient 9	220	225	+ 2.2%
Patient 10	222.75	225	+ 1%

Variation of measured dose with prescribed dose in the case of supraclavicular field

[illegible] The only inference [illegible] dose measured using [illegible] in the SCF is less than the prescribed dose whereas for tangential field it is more. The variation [illegible] for both compared to TLD. This raises the [illegible] of a bias in [illegible]:-
1. [illegible] paper?
2. TLD [illegible] Reason? [illegible]

Verification of dose Homogeneity

Table 6 shows the uniformity of dose in the breast. Three positions are considered for the measurement. Dose homogeneity is seen in 80% of the cases. However, It varies from the calculated value. This variation is found to be from 0.4% to 28%. Most of the cases are having a variation below 15%.

Dose homogeneity tests were carried out in 50 out of 80 patients. The variation of dose from patient to patient depends on the patient contours. As the technique is same for all cases, the patient contour, which depends on the patient breast geometry, the positioning of the patient, and the implementation of the treatment results in the variations. Aged patients breasts sag and hence contours differ. These differences may be attributed to the variations observed in the dose.

Day to day variation in patient dose during treatment

Table 7 gives a day to day variation in patient dose during treatment. A variation from 3 to 10% is found in Medial Tangent and 0.76 to 15% in Lateral Tangent techniques. Excepting in one case dose variation is found less in the case of lateral tangent technique. Table 7 also gives the variations in the day to day dose measured using thermoluminescent chips.

The results of the day to day variations have already been reported by the author[63], and are given in **Table 8**. A variation of 2 to 10% is observed in the case of tangential field using diode detectors. Table 8 shows the variation is less than 5% in Supraclavicular Fossa.

TABLE – 6 [Verification of dose homogeneity]

Sl. No.	Dose calculated (entrance + exit) cGy	Dose measured cGy				Variation in %
		MT (1)	LT (2)	Nipple (3)	Average of 1, 2 & 3	$\frac{\text{Measured-calculated} \times 100}{\text{Calculated}}$
1.	209	166	180	175	174	−17
2.	230	262	225	250	246	+ 7
3.	317	360	360	212	310	−2
4.	256	258	269	195	246	−6
5.	218	178	179	179	179	−18
6.	228	185	170	237	197	−13
7.	226	180	135	196	168	− 26
8.	226	175	150	163	163	− 28
9.	200	173	175	160	169	− 15
10.	220	195	210	220	208	− 5.3
11.	179	176	197	208	194	+ 8
12.	233	225	235	235	232	− 0.4
13.	244	223	230	212	221	− 9
14.	196	220	180	215	205	+ 4.5
15.	152	157	172	170	166	+ 9

TABLE – 7

Sl. No.	M.T	L.T
1.	5.45	0.76
2.	9.75	1.8
3.	10.7	8.5
4.	5.5	8.75
5.	9.3	4.6
6.	2.2	2.1
7.	3.9	4.3
8.	2.4	15.3

Day to day Percentage variation (using Thermoluminescent discs)

How many observations? How many are +ve values?

TABLE – 8

Sl. No.	M.T	L.T	SCF
1.	8.4	2.8	3
2.	4.1	2	1.5
3.	2	3	2
4.	8	4.2	3.8
5.	3	0.8	1.1
6.	6	1.9	1.9
7.	9	1.2	1.7
8.	7	3.6	3
9.	10	2.1	2.8
10.	5	0.9	.9

Day to day Percentage variation (using diodes)

How is this different from the values shown in the published paper? ([illegible])

[illegible]

Usually a total variation of 7% (including treatment planning and execution from the prescribed dose) is allowed in the case of radiotherapy treatment. However in our study of day to day variation in dose the variation is found to be more than this value. A small difference in the patient positioning in day to day set up results in a large dose variation, which could be one of the reasons for the variations seen in our measurements. Immobilization devices, careful position and use of breast board help reduce this variation. The patient positioning and the gantry angle in the setup also have a very important role, in the treatment.

Dose variation in two cobalt machines

The dose from the two cobalt therapy machines is not easy to compare in patients as the dose at different points is affected by the patient contour. However in table3 a comparison of dose with two machines was made. As the contour differs, dose at different points varies. Accordingly to make the comparison more meaningful, a phantom study, wherein such variations arising out of different contours will not be there, was also carried out in this work. A phantom made by tissue equivalent material was used for dosimetry purpose [57].

A comparison between the doses measured with the two machines is shown in **Table 9**. Doses at medial tangential positions, lateral tangential positions and at nipple positions were found out from both machines, with and without half beam block. Thermoluminescent chips were used for the measurement. The measurement was taken using a wax phantom [52] as already mentioned. The medial tangential positions, lateral tangential positions and at nipple positions were marked on the phantom. The beam angulations and collimator angulations were kept same for both the machines.

TABLE – 9

Sl. No.	Elite 100						Theratron 780E					
	With HBB			Without HBB			With HBB			Without HBB		
	M.T	L.T	Nipple	M.T	L.T	Nipple	M.T	L.T	Nipple	M.T	L.T	Nipple
1.	110	190	178	191	196	180	132	147	219	150	163	219
2.	103.6	164	212	224	164	240	158	189	177	173	197	219
3.	150	171	156	214	204	183	175	171	178	177	162	176
4.	121	177	165	210	188	208	155	169	198	167	174	205

Comparison of dose in two cobalt Machines with and without half beam block

In our study it is found that with half beam block, the average dose is less in Elite 100 than Theratron780E. Without half beam block dose is high in Elite100. Another important factor is that the half beam block reduces the over all dose at these points. When thermoluminescent discs were kept under the chest wall, in the wax phantom during irradiation the dose received by the discs was 125cGy with beam block and 209cGy without block using Theratron 780E while the values are 181.5cGy with block and 223cGy without block using Elite 100. This shows that half beam block helps to reduce dose to the organs like lung and heart under chest wall.

It is important that the over all variation starting from the planning to the end of the treatment should not be more than 7%. However, in our study a variation of dose between the measured and the calculated value was between 10-13%. The variation is mainly attributed due to the errors in the setting up of the patient in the machine and the treatment planning. In addition to this lung correction for that part of the lung in the treatment volume was not taken into account during dose computation. The lung density is less than that of normal tissue. Accordingly the attenuation of radiation, which depends on the density of the medium through which it passes, is less in lung tissue. A lung correction[53,54] according to the involvement of lung volume helps in reducing the variation.

For a lung correction to be applied in the computation of dose, the volume of lung has to be measured precisely. A computed tomography image and 3D treatment planning is necessary for this purpose. As we do not have this facility in our laboratory, we have used half beam block to reduce the volume of lung involved in the treatment field as much as possible.

Contralateral breast dose measurement

The measurement of contra lateral breast dose was carried out using CasO4: Dy Chip thermoluminescent dosimeters (TLDs). Table10 shows dose at different points (i) on nipple, (ii) a point at three centimeter lateral to medial tangent entry point, (iii) a point 3cm upper to nipple point and (iv) a point at 5cm lateral to the nipple in contra lateral breast. Vethanayakam et al. [34] reported that the dose to the contralateral breast is mainly from the scattered radiation from machine, tissues etc. When dose, due to the scattered radiation, at different points of contralateral breast in patients was measured, the dose at the point near medial tangent was found to be higher than at other points. The average dose to contralateral breast, by considering all the four points, with all the three fields like medial tangent field lateral tangent field and supraclavicular field, is found to vary from 4 to 13cGy per fraction.

A very low dose may cause carcinogenesis [44,45] which has to be avoided. From **Table 10** we can see that the dose near to medial line is more, while dose at nipple position of contralateral breast and upper part of the breast near nipple is having almost same value and is less than the one at medial line. The dose at lateral side is negligibly small.

In 45 out of 60 patients considered in the present study, dose at the nipple position in contra lateral breast was measured as explained earlier in chapter 2. **Table 11** shows the dose variation in nipple position from these measurements. From this table we can clearly see that there is a standard deviation of dose from 2 to 16cGy per fraction. A total dose difference from 50cGy to 300cGy is found for the complete treatment and this dose is 2 to 8% of the prescribed dose for the affected breast. However, Chougulere et al. [46] reported a total dose of 111.25 to 223.5cGy without half beam block in their measurement of breast doses due to primary irradiation for malignancy. We can also notice that at the lower end while our dose is lesser than that of Chougule[46] et al, at the higher end their dose is less than our dose.

Ramachandran TP et al. [47] found a contra lateral dose of 99 to 608 cGy due to all fields for complete treatment which is higher than the values of our investigations.

TABLE - 10

Sl. No.	Dose at different points				Average Dose/fraction
	1	2	3	4	
1.	8.66	16.65	3.24	7.72	9.07
2.	3.8	13.72	1.13	3.04	5.42
3.	4.67	12.17	1.71	4.2	5.67
4.	12.2	19.5	7.8	3.3	10.7
5.	3.1	11.13	3.28	2.14	4.91
6.	5.51	4.83	4.39	1.97	4.18
7.	5.26	13.75	6.20	2.12	6.83
8.	4.61	12.5	6.53	1.49	6.29
9.	2.26	12.74	2.43	1.0	4.61
10.	9.75	8.98	7.61	3.1	7.36
11.	10.06	18.8	10.52	2.52	10.48
12.	11.33	26.6	10.91	3.07	12.98
13.	3.22	6.94	3.22	1.82	3.8

Doase at various points on contra lateral breast as shown in fig 15

TABLE - 11

Sl. No.	Nipple position (dose/ fraction)	Total dose	Variation
1.	8.66	242.5	4.85
2.	12.25	245	6.13
3.	3.03	84.84	1.7
4.	5.26	147.28	3%
5.	2.26	63.28	1.27
6.	10.08	282	5.6
7.	13.34	266.8	6.67
8.	3.22	64.4	1.61
9.	6.9	138	3.45
10.	10.78	215.6	5.39
11.	2.52	50.4	1.3%
12.	6.62	132.4	3.31
13.	16.8	336	8.4
14.	13.04	260.8	6.52
15.	10.58	211.6	5.29
16.	3.35	67	1.68

Sl. No.	Nipple position (dose/ fraction)	Total dose	Variation
17.	7.17	143.4	3.6
18.	7.5	150	3.75
19.	14	280	7
20.	5.26	147.28	2.95
21.	2.26	63.28	1.27
22.	14.85	212.5	4.3
23.	11.05	231.2	4.6
24.	15.57	311.4	7.8
25.	13.9	278	7
26.	15.9	318	8
27.	14.8	296	7.4
28.	27.3	546	13.7
29.	5.34	149.5	3
30.	6.07	121	3.4

Dose variation at nipple position of contralateral breast

Doses with all the three fields like medial tangent, lateral tangent and supraclavicular field together and independently with each one of them were measured and these are given in **Table 12.** The size and shape of the contralateral breast and the type of techniques used in the treatment affects the Contralateral Breast (CLB) dose. In our study, the technique is same for all the cases, though the angle of gantry is different. Therefore the shape and the size are the main contributors for the different doses as seen in the Table12 for contralateral breast. As the breast sags with age, the dose received by contralateral breast [59] is expected to vary. As the age increases the average dose to the contralateral breast decreases.

On comparison of contralateral breast dose from the two cobalt machines as in **Table 13,** it is seen that Elite 100 gives less dose to contralateral breast.

We had conducted the measurements with 20 patients, each in the two Cobalt machines. All the cases were treated with half beam block. Even if we consider the patient anatomy, it was found that the dose to contralateral breast is more when source to axis distance is 80cm compared to source to axis distance is equal to 100cm. This is because the scattering dose from block is more when it is near the breast [48].

As we could not treat the same patient with both cobalt machines, a phantom was used for comparison of doses with two machines. This also showed that dose to contralateral breast is more in Theratron 780E as in **Table 14**. This excess dose is seen with half beam block. This is because the half beam block is nearer to contralateral breast when source to surface distance is small. Half beam block increases the dose, due to scattering as already pointed out, in contralateral breast though it decreases dose to the underlying lung and heart while treating the affected chest wall.

TABLE – 12

Units: cGy?

Sl. No.	M.T	L.T	SCF
1.	6.3	1.4	4.5
2.	7.88	2.21	2.94
3.	3.93	1.112	2.16
4.	5.07	6.43	
5.	6.57	2.0	2.77

Dose (average) due to each field to the contralateral breast with medial tangent field, lateral tangent field and supraclavicular field.

1) How many patients were covered for each [illegible]?
2) Was it done on the same patient many times?
3) [illegible] in the machine?
4) Was a [illegible] used?
5) Are these values statistically [illegible]
6) How are the above 5 settings statistically compared?

TABLE – 13

Sl. No.	Elite 100	Theratron
1.	5.74	9.76
2.	3.72	12.1
3.	9.24	9.52
4.	6.4	10.3
5.	7	11.4

Dose to nipple position of contralateral breast with two cobalt machines

TABLE - 14

	ELITE 100			THERATRON 780		
	MT	LT	Nipple	MT	LT	Nipple
Without Half Beam Block	17.5	10.3	66.5	22.7	17.08	
	22.4	13	78	18.36	17.4	83.5
	20.6	15.5	53.3	26.2	21.6	118.5
Total	20.2	12.9	65.9	22.42	8.7	101
With Half Beam Block	14.68	10	17.49	29.5	21.35	
	15.72	11.5	17	14.4	10	17.9
	16	12.2	12.19	17.05	15.65	22.6
Total	15.47	11.2	15.6	20.3	15.7	20.3

Comparison of doses (cGy) to contralateral breast with two cobalt machines (The study conducted in wax phantom)

In our study on a day to day basis we have seen variation of dose in contralateral breast. This is due to the change in setting up of the patient in the machine. The out put of the machine will not change as same radio nuclide is used during the entire treatment period. Therefore the variation seen could be attributed to the variations in setting up of the patient from day to day. While setting up of the patient, the way the patient lies on the treatment couch and how the arm is abducted cause these variations. An immobilizing device as described earlier [chapter 2] helps to achieve the reproducibility of the patient position in the machine and reduce the variations.

Dose measurement in patients treated with Accelerator Beams

Table 15 gives a comparison of doses measured by thermoluminescent chips, used for treatment using accelerator beam which were calculated with the treatment planning system.

In this comparison the dose at the entry point is not the dose at the maximum point D_{max}. Dose maximum is at a depth of 1.6cm in tissue for 6 MV photon radiations. Therefore a tissue equivalent material with 1.6cm thickness had to be placed over thermoluminescent discs to get the dose at D_{max}. This affects the dose delivered. Accordingly in the present studies, a set of points of interest read out from treatment planning system were identified on the contour and comparison is made with the dose measured at those points. A small difference in the identification of the points compared may affect the dose. Therefore in the calculated values itself there is a 2-3% deviation between the doses.

It can be seen from the table16, a variation below 7.0% is found in four of the cases in Medial tangent and Lateral tangent entry positions. Only in one case it is different and is found to be higher. In nipple position the variation for the above four cases is from 10 to 20%.

TABLE – 15

Sl. No.	Measured in TPS cGy			Measured by TLDs cGy			Variation %		
	MT	LT	N	MT	LT	N	MT	LT	N
1.	1684	2114	1842	1638	1963	2058	–2.8	–7.2	+11.7
2.	3517	3894	5000	3550	3700	4000	+0.9	– 5	–20
3.	2832	2924	3857	3000	2900	4275	+ 6	0.8	+10.8
4.	3023	2921	2435	2550	2500	3725	–15.6	–14	+ 53
5.	3176	3400	4766	3350	3450	4000	5	+1.4	–19

Comparison of Dose Measured with accelerator and with treatment planning system

The points of entry and exit were marked on the patient and the thermoluminescent discs were placed at these points. These points were easily identified in planning system also. A small change in position longitudinally would not cause much difference in the dose. C.T cross sectional cut near the medial tangent points and lateral tangent points were taken for the dose comparison. In the case of nipple, the contour is different at nipple position. The change of contour from upper part of the body to lower part is significant. Therefore a small difference in the cut section from CT taken for measurement is expected to give a large variation. This explains the large variation seen in the case of dose at nipple positions.

In the case of electron beam, doses at different positions like entry, exit and nipple were found out using, again, thermoluminescent discs. The dose was found to be 265cGy per fraction, 208cGy per fraction and 220cGy per fraction.

Dose at contralateral breast is also measured in the case of 6MV photon beams. We have selected two positions: (A) nipple position and (B) a point 3cm lateral from medial border of medial tangent field towards contralateral breast side and the study was carried out in the above 5 patients. These points give an idea of the average dose absorbed in contralateral breast.

The dose at these two positions in contralateral breast was measured using thermoluminescent discs. The percentage of dose contributed from the dose prescribed to the treated breast is given in **Table 16**.The dose contribution varies from 1.7% to 3.7% at nipple positions. At the point near to medial line it is found to vary from 3.8% to 7.9%. The total contribution was less than 100cGy at the nipple position and less than 200cGy in the medial region for a complete treatment. From Table 16, we can see that the contralateral breast dose with the accelerator 'Elekta Precise', is lesser compared to the dose to contralateral breast when treated with cobalt therapy machines. In Elekta Precise the beam modifying devices like wedge is above the collimator and multi-leaf collimators are used to cut half of the

TABLE – 16

Sl. No.	Dose in cGy		% of contribution of dose	
	A	B	C	D
1.	3.7	8.3	1.7	3.8
2.	3	10.6	1.7	6
3.	3.7	11.1	2	6
4.	8.4	12.7	3.7	5.6
5.	6.7	18	2.9	7.9

5. 12·14 [illegible]

A & B represents the points on the nipple position and 3cm lateral to medial line of contralateral breast.

What was the dose to the affected breast in these cases?

beam instead of half beam block. Therefore the scattered radiation is less in Elekta Precise in breast irradiation technique. This reduces the contralateral breast dose.

Dose – Volume histogram

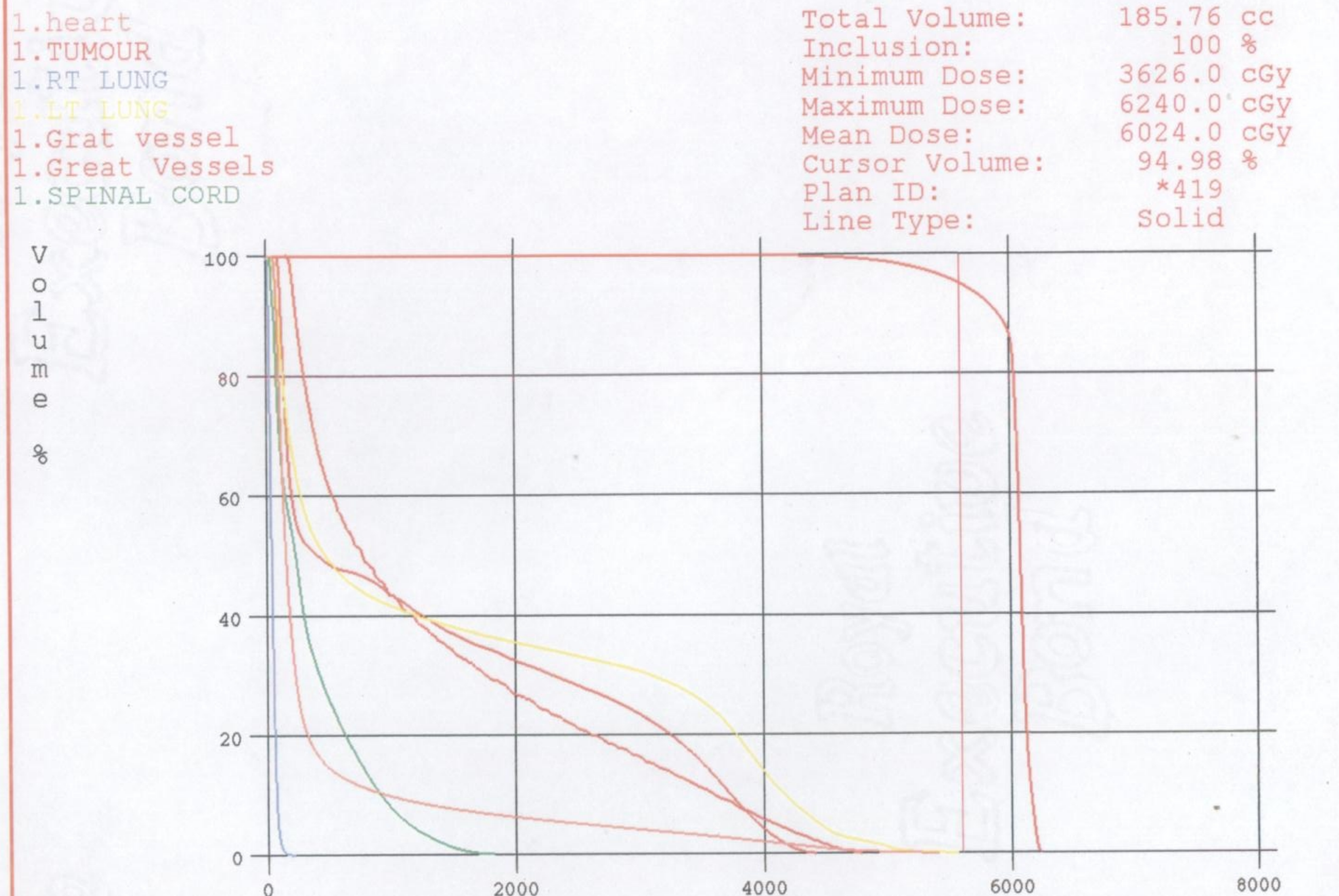
The dose volume histogram is a planning tool. This gives the volume of the organ receiving a dose within a specific dose interval. The volume is represented either as the percentage or fraction of the total volume of the organ. The dose volume histogram helps to do quantitative assessment of dose at different organs during the treatment planning. In our study the volume was represented as percentage.

Dose volume histograms of different cases show that in most of the cases the volume of lung that receives 1000 cGy was less than 20% and the volume of tumour that got 5000cGy was100% as shown in **fig 22**. For all the cases treated using linear accelerator, 'Elekta Precise', dose volume histogram (DVH), shows that dose to normal cells, especially in lung is very less. When dose distribution is studied with 3D treatment planning system, it is found that dose in heart is also very less in the above cases. We have also studied the dose in the lungs inside the treatment volume and outside the treatment volume using treatment planning system and found that the dose outside the treatment volume is 10% lesser.

Comparison of dose measured with cobalt machines and Accelerators at AIMS with treatment planning systems and with thermoluminescent discs

This comparison is not easy to make as the patient contours; type of treatment etc affects the dose at different points of interest. In addition the technique and the radiation energy are different in cobalt machines and accelerators. However, when doses to contra lateral breast were studied in

DVH: 06RT0727,AMBIKAKUTTAPP



5603
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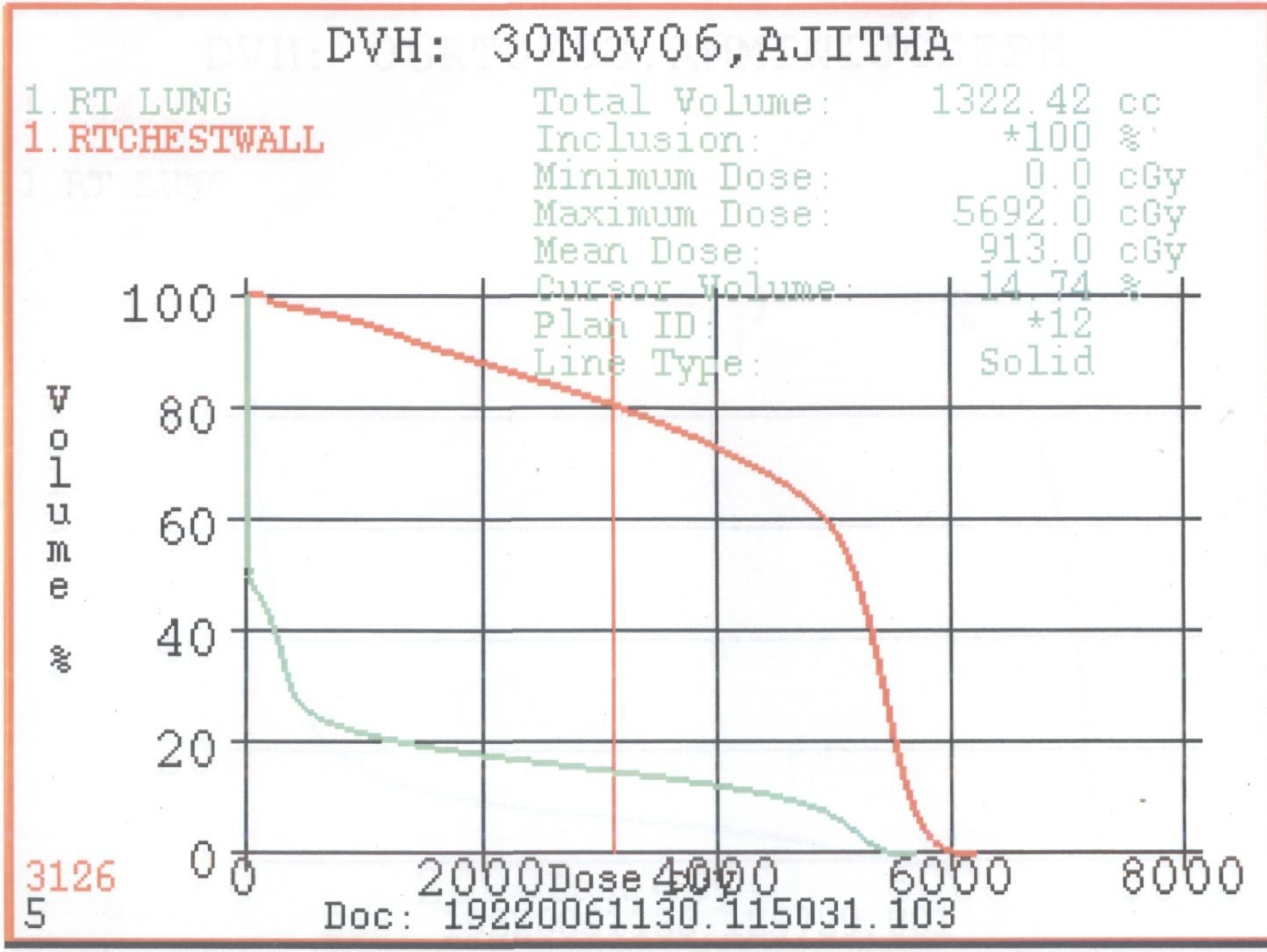
patients treated with these machines, the contralateral dose was found to be less in patients treated with accelerator.

Dosimetry was done on 3 patients treated in the cobalt machines in treatment planning system. Two of them were treated with Elite 100 and one was ~~in~~ treated with Theratron 780E. In addition dosimetry was also done with the Xio 3D treatment planning system, 2D treatment planning system and also with thermoluminescent discs.

Dose volume histograms of these cases were also taken. It is found that in one case the percentage of volume that gets more than 1000cGy was 26% as shown in **figures 23 and 24**. Out of the three cases considered, two cases were treated with 50 Gy in 28 fractions and the third case with 40 Gy in 20 fractions with cobalt machines.

Table 17 shows a comparison of doses in the case of the three breast cancer patients treated with cobalt machines and compared with treatment planning system data at AIMS. These comparison was among the doses measured using thermoluminescent discs at the points like medial tangent, lateral tangent, Nipple positions, the dose read out with 3D treatment planning system and the dose read out with 2D treatment planning system (Theraplan at Medical college, Calicut)] **Table 18** shows the comparison of variation between 3D treatment planning system and thermoluminescent dosimeter measurements together with variation between 2D treatment planning system and thermoluminescent dosimeter measurements. Table18 also gives comparison of variation between the two treatment planning systems. The variation is high in nipple position. This is because of the selection of CT cut for the planning. Any difference in the CT cut taken for the planning affects the dose measurement in the nipple point by the planning system.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1.RT LUNG
1.RTCHESTWALL
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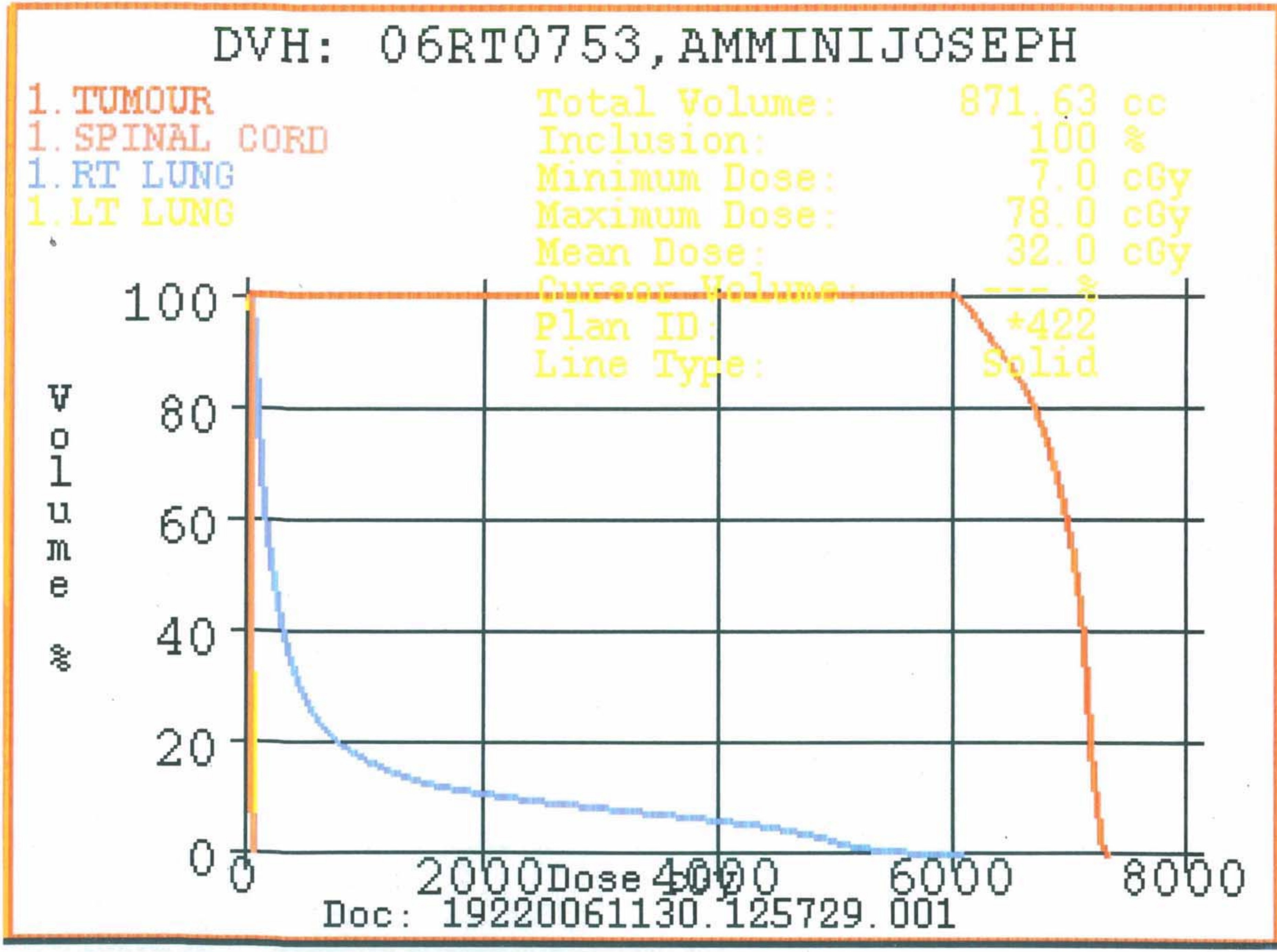
Inclusion: *100 %
Minimum Dose: 0.0 cGy
Maximum Dose: 5692.0 cGy
Mean Dose: 913.0 cGy
Cursor Volume: 14.74 %
Plan ID: *12
Line Type: Solid
Volume %
100
80
60
40
20
0
0
2000
4000
6000
8000
Dose cGy
3126
5
Doc: 19220061130.115031.103



DVH: 06RT0753,AMMINIJOSEPH
1.TUMOUR
1.SPINAL CORD
1.RT LUNG
1.LT LUNG
Total Volume: 871.63 cc
Inclusion: 100 %
Minimum Dose: 7.0 cGy
Maximum Dose: 78.0 cGy
Mean Dose: 32.0 cGy
Cursor Volume: --- %
Plan ID: *422
Line Type: Solid
100
80
60
40
20
0
Volume %
0
2000
4000
6000
8000
Dose
Doc: 19220061130.125729.001

TABLE – 17

Sl. No.	Measurements in 3D TPS			Measurements in 2D TPS			TLD measurements		
	MT	LT	NP	MT	LT	NP	MT	LT	NP
1.	4613	5053	5770	3619	4754	4303	3528	4284	4564
2.	4183	3861	4763	3810	3930	4420	3510	3270	3570
3.	4120	3963	5985	4568	4318	4568	4032	3920	4144

Comparison of Dose Measured by three methods

TABLE – 18 [Variation of doses]

Sl. No.	Variation between 3D TPS and TLD reading %			Variation between 2D TPS and TLD reading %			Variation between 3D TPS and 2D TPS reading %		
	MT	LT	NP	MT	LT	NP	MT	LT	NP
1.	23	15	20	3	10	5.7	27	6.2	34
2.	16	15	25	8	17	19	10	2	7.2
3.	2	1	69	11.7	7.2	9.3	9.8	8.2	31

Dose at critical organs like lung and heart of the three cases mentioned was also studied with the two treatment planning systems. Comparison of doses at points, in the lung inside the treatment volume, outside the treatment volume and in heart (in left sided breast cancer cases) of these cases are given in **Table 19.**

Dose at the points in lung and heart was found to be less because all the three cases were treated with half beam block. However for breast cases treated with accelerator beam the dose to the critical organs was lesser.. Accurate planning and tumour volume prescription with the aid of CT simulator and planning system before the treatment reduces dose to the critical organs.

Conclusion

In our study dosimetry was done in mastectomy cases as well as breast conservative cases. 95% of breast cancer cases coming for radiotherapy are after mastectomy. Adjuvant chemotherapy is also given for these cases. Radiation is given to the chest wall to reduce local recurrence in the case of mastectomy patients. Dosimetry was done with two cobalt machine and a comparative study was carried out.

In the present study dose was measured with thermoluminescent discs at various points of affected breast. It was found that variation of dose from the prescribed dose was high in most of the cases. Generally the overall variation starting from the planning to the execution of treatment should not be more than 7.0%. The excess variation seen in the present study may be attributed to variations in several parameters such as (1) output measurement of the machine, (2) treatment volume prescription, and (3) planning and the treatment. For the 80 patients considered in this study, it was seen that the variation after planning and treatment itself is more than 7%. The treatment should be planned carefully with the machine or simulator

TABLE – 19

Sl. No.	Machines	Lung out	Lung in	Heart
1.	Cobalt-60 machine	459	5984	
2.		426	4018	376
3.		499	4972	
4.	Linear Accelerator	282	4379	
5.		182	3061	
6.		367	5014	
7.		339	5328	129

Dose (cGy) in critical organs in the case of ca-breast studied in TPS to reduce this variation. As we do not have the facilities for treatment and planning with very high accuracy, the afore mentioned 7% is unavoidable. Hence this resulted in the larger variations as reported in our studies here.

Day to day variation in treatment dose is found to be from 2 to 12%. In TLDs as well as solid state detectors the variation is same. This variation implies that treatment set up reproducibility is not accurate. A small tilt in patient body and changes in patient position contribute a large variation in dose measured. Even the positioning of the arm will change the body contour which effects the involvement of lung in the treatment volume. An immobilization device and breast board helps to reduce this variation. In the absence of these devices, care should be taken to position the patient very accurately. Unlike other cancer areas, breast geometry is very complex. The underlying organs, contour of the body, etc make accurate planning and positioning of the body highly essential. The gantry angle, collimator angle of the machine should be kept same, during the planning and through out the treatment. The non availability of breast board and immobilization devices causes the above variations.

Only mastectomy cases were studied with Cobalt machines. Therefore wedges are not used during the treatment. As only the chest wall is irradiated a half beam block was used to cut lower half of the beam which reduces dose to lung and heart. However, it is found that dose to contralateral breast increases when block is used.

Measurements, with a phantom, of the dose to the lung surface with and without half beam block show that half beam block reduces dose to lung. This is an advantage as it reduces the chance of lung pneumonitis later. A similar trend is also seen with treatment planning system.

However, the overall dose received in the treatment volume is also reduced with a half beam block which is not very desirable in many situations. The dose to any point on the body is due to primary radiation and scattered radiation from half beam block and the tissue. Here though significant scattered radiation from block is present, the scattered radiation from tissue is reduced due to the block.

Our studies show that half beam block increases, contra lateral breast dose. Radiations which cause late affects such as cancer do not have a threshold value. The probability of induction of cancer increases with the dose absorbed. Even very low dose can cause cancer. It is found in an earlier study by Heyes et al [16] that a negligible dose even from mammography examination can cause breast cancer. During the radiotherapy of carcinoma breast the contralateral breast gets radiation which is found to be more than the dose received by breasts during mammography examination where low energy X-radiation is used for imaging. Therefore, chance of getting cancer in contralateral breast is high, if the radiation dose to this is high. This can be avoided by using shields. However it is not easy to put a shield over the patient during the treatment[64]. It is also found that dose to contralateral breast is less when source to surface distance is large. The CLB dose is mainly due to low energy radiation and electron contamination from half beam block and machine collimators. The energy of these radiations falls rapidly as the distance of the skin from blocks increased due to the attenuation in air. It is also shown (49) that wedges, used for treatment, increases contralateral breast dose. A higher source to surface distance, like SSD = 100cm decreases contralateral breast dose.

The contour of the patient affects the dose to contralateral breast. If the patient is old the breast sags away from midline, and the dose decreases. Lean patients and fat patients get different doses to contralateral breast.

As the cancer in contralateral breast is a late effect, it may take 10-15 years to appear (65). Therefore from all the reasons given above, it is better to treat young patients with machines having large source to surface distance.

In our work with accelerator, most of the cases studied are breast conservative surgery cases. Some are mastectomy cases. The treatment technique depended on the state, stage, contour of the patient, nodal involvement and type of surgery.

In mastectomy cases, chest wall was usually treated with electron beam. Supra clavicular Fossa and nodes in post axilla were treated with photon beam if nodes are involved.

In Breast Conservative Surgery cases, the treatment technique depended on stage and shape of body contour. All the cases were thoroughly planned in a 3D treatment planning system before the treatment. Multi-leaf collimators were used to shape the treatment volume and hence give conformal radiotherapy.

The dose, from the conformal tangential fields to irradiate the breast, is less for the lung and heart[41] (in the case of left breast). Therefore the toxicity to these organs is less compared to rectangular treatment fields. The shape of the breast (especially in the case of breast conservative therapy) target volume is never rectangular and the use of rectangular treatment fields therefore always results in the irradiation of more lung or heart than necessary to adequately irradiate the breast.

When treated with accelerator using multi-leaf collimator, the contralateral breast also gets radiation. If the distance between the surface of the body and the head of the accelerator is more this dose can be reduced.

After lumpectomy, as electron beam is not sufficient to treat the whole breast high energy photon beam with 6MV photon was used. The technique used depends on the shape of the patient contour and nodal involvement. A thorough planning had done before treatment in conformal therapy with wedge. Missing of tumour and hot spot is a possibility since we use irregular shapes with multi-leaves for the treatment. Images from a C.T simulator help to do a thorough planning with treatment planning system. Therefore in our work, images of all the cases were taken with computed tomography simulator.

The positioning of patients in machines every day is very important for reproducibility. This helps to give accurate dose. Usually breast cancer patients are treated in a supine position. This position is comfortable for the patient and enables the selection of a wide range of beam directions. The use of fixation devices, arm support, immobilization devices influence the errors in the set up and also influence the volume of the organs at risk inside the treatment fields. The arm position decides the volume of lung in the treatment volume. Now a days breath hold techniques, or respiration gated techniques are available to reduce the volume of lung in the treatment volume. The variations can be avoided with the help of these newer techniques.

SUMMARY

Sushama.P "Study of dosimetry in various cases in Radiotherapy" Thesis.
Department of Physics, University of Calicut, 2007

CHAPTER - 4

SUMMARY

SUMMARY

Breast cancer is very common throughout the world among women. There are different groups and organizations throughout the world to help and give guidance to the people who are suffering from this. In the year 2000, the Early Breast Cancer Trialists' collaborative group (EBCTCG)[(66)] published the results of a new meta analysis of randomized breast cancer trials comparing surgery, being either mastectomy or breast conserving surgery, with and without adjuvant radiotherapy in early stage breast cancer. In that study over a period of 20 years, overall survival of early stage breast cancer with mastectomy or breast conserving surgery is found out to be 35.9%. This could be increased to 37.1% if adjuvant radiotherapy is given. Therefore surgery and radiotherapy are the most important methods for loco regional breast cancer treatment. Chemotherapy is also given along with the other two methods in our country.

The EBCTCG trials showed that surgery was not enough to control the breast cancer[(67)]. Earlier, radiotherapy was usually given after mastectomy in which entire breast and regional nodes are removed. Later the cosmetic problems and the result that radiotherapy after mastectomy and breast conservative therapy give similar results, gave way to conservative therapy. The new advanced imaging methods together with the awareness of people help, now a days, to find out the disease at early stage. This helps to improve the breast conservative therapy.

However, in our country ignorance about the various aspects of the disease and treatment methods is very high. Therefore the breast cancer patients coming for the treatment are mostly at a later stage of disease.

With respect to most other common cancers, a high local control rate and good overall survival can be achieved for the majority of breast cancer patients with current surgery and adjuvant radiotherapy techniques.

However a concern was there for the adjuvant radiotherapy. Earlier it was found that adjuvant radiotherapy though decreases local recurrence, increases mortality due to radiation toxicity. This is because of the radiation dose to the sensitive organs like lung, heart, and contralateral breast. The newer techniques help to reduce dose to these organs and improve the overall survival rate.

At our centre it is seen that the recurrence of disease is less after radiotherapy for patients with mastectomy. These patients are treated with chemotherapy also. In addition, there are cases with brain metastasis, edema in hands and spine metastasis. A multidisciplinary approach is needed for further improvement of breast cancer treatment. While, the surgeon does the surgery the oncologists decide the target to be treated with radiation and we feel that there is no proper coordination between these two important wings of treatment.

Newer techniques are there to give accurate dose delivery. Intensity modulated radiotherapy helps to give high dose to tumour while giving low dose to organs at risk.

In our investigations, dosimetry studies were carried out in order to find out dose uniformity in the treatment volume of breast, other points of interest such as dose entry point, dose exit point and nipple point and dose to critical organs. The present investigations clearly show that the dosimetric studies with accelerator beams and immobilization techniques provide better and accurate results in delivery of dose and hence the treatment. Our studies also show that, it is very difficult and sometimes impossible to reproduce the day to day geometry with Cobalt-60 machines where immobilization devices are not available in treating the patients. This irreproducibility of the geometry leads to large variations in the dose delivered as our results show. We strongly believe that the present work clearly suggests that radiation treatment of carcinoma breast requires proper immobilization and better radiation delivery machanisms.

The combined work of radiation physicists, clinicians (oncologists, surgeons and radiologists), and technologists help to give accurate dose without affecting the critical organs. When planning is not good, it affects the radiation delivery and the treatment. Similarly accurate planning with organs marked is necessary for good treatment and accurate dosimetry. Finally any error in implementation will affect the outcome of the treatment.

A thorough and systematic study in all these discipline is necessary for further improvement of the techniques Intensity Modulated Radiotherapy gives high dose to the tumour, but if the planning is not accurate, chance of missing of the tumour is also high. New machines are being developed in the field of radiotherapy and imageology which give high dose to tumour and negligible dose to the normal tissues. But an accurate plan will be necessary for this. Dosimetry helps to do the cross checking of dose delivery. Any research in this field will help to improve the outcome of radiotherapy.

In conclusion, Our work, we believe, in conducting the present dosimetry studies using some of these techniques clearly shows the advantages of these methods[45]. We also believe that our work helps in motivating future studies for the improvement of the radiotherapy treatment techniques for the patients with breast cancer and provide sufficient data for further investigations in this area.

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DAY TO DAY VARIATION IN PATIENT DOSE IN TREATMENT EXECUTION OF CARCINOMA BREAST

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ABSTRACT

Radiotherapy plays an important role in the treatment of patients with breast cancer. The rationale for post mastectomy radiotherapy is to prevent recurrence of cancer in the chest wall, skin, mastectomy scar and the regional nodes (supra clavicular nodes and internal mammary nodes). Complexity of the shape and position of the irradiated volume of carcinoma breast, make it necessary to give a careful attention to the positioning of the patient and the technique involved. Patient has to be positioned carefully everyday in order to reduce doses to lung, contra lateral breast, thyroid etc. Radiation dose measurement is done for 20 cases with carcinoma breast using semiconductor detectors. The diode is kept in the central point of the entry field and the dose is measured in the case of tangential field treatment. Tangential field treatment is carried out using half beam block to reduce dose to the underlying lung tissue. The exit dose is also measured on the same day. The dose through supraclavicular field (SCF) is given in 20 equal intervals of dose and the dose is measured using the semiconductor detectors. Every day dose is compared and the variation if any is found out. It is found that in about 50% of the treated cases more than 5% variation exists in the case of tangential treatment technique and less than5% for SCF treatment.

DAY TO DAY VARIATION IN PATIENT DOSE IN TREATMENT EXECUTION OF CARCINOMA BREAST

INTRODUCTION

Breast cancer is one of the most common cancers in India. Radiotherapy is an important method for treatment of cancer patients. In most of the Cancer centers in India, Co-60 source is used for radiotherapy treatment. The breast or the chest wall is usually treated using two tangentially directed fields with a dose of 4500cGy to 5000cGy over five to five and half weeks. The fields are designed to give radiation to the chest wall and irradiate the smallest amount of underlying lung and also in the case of left sided breast treatment, the lowest possible exposure to the heart. The half beam block helps to bring the dose to the underlying lung tissue as minimum as possible. In patients with positive nodes, a small supra clavicular field is employed which irradiates the supraclavicular nodes at the apex of axilla.

Conservative treatment of Carcinoma Breast is increasingly preferred. However in many places in India patients will have to undergo radical mastectomy as early detection of breast cancer is not effective. Because of the complexity of the breast anatomy, a thorough planning is required in the treatment of breast cancer. The dose given to the tumour can be measured by using various dosimeters. Thermoluminescent dosimeters, port films and semiconductor diodes are some of the dosimeters used for this purpose. In the present study, the doses are measured at the entrance and exit points in the tangential treatment and supraclavicular treatment, using semiconductor detector.

MATERIALS AND METHODS

In the present study patients who underwent post operative radiotherapy after radical mastectomy were considered. Radiation dose at the entry point and exit point were measured in all cases everyday using semiconductor detector. The dose variation with reference to the prescribed dose and day to day variation in the individual patients is also studied. For this study about 20 cases of patients with Carcinoma breast is considered.

The present study was carried out in the machine-Theratron 780E of the Calicut Medical College facility . All the cases studied, are treated with four field technique. Out of the four fields, two are tangential fields, one is supraclavicular field, and the other one is posterior axillary field. The upper border of the tangential field lies at the level of the manubrium sterni and the lower border at 1 to 2 cm below the breast or mastectomy scar, which ever is lower. The lateral border lies at the midaxillary line and the medial border in the midline. If internal mammary nodes are involved the medial border should be shifted to 3 cm across the midline. The inferior edge of the SCF coincides with the superior edge of the tangential pair. The medial edge is along the midline and the lateral border is just lateral to the apex of supraclavicular fossa. (fig-1)

The dose given through tangential field is 4000cGy in 20 equal intervals, in supraclavicular field it is 4500cGy in 20 equal intervals and the posterior field is a single field, usually of 600cGy. The dose is normalized at the midpoint of interfiled distance for tangential fields(fig2). As the treatment is an SSD technique, using percentage depth dose, the dose at dose maximum point(Dmax) is found out. The calculated dose at Dmax may have some variation depending on the inter field separation and the stage of the tumor,from patients to patients.

In the SCF, the dose prescribed is at Dmax and as the measured dose is also at Dmax

As lung is a critical organ in the treatment of Carcinoma breast, the tangential field technique is executed using half beam block[2,3]. The lower half of the beam is cut-off using a 5cm thick lead block. A reproducible position is required for successful application of breast techniques using fixed gantry angles for everyday treatment.

To find the day to day variation during the treatment, a solid state detector is used[4]. The solid state detector is 'Isorad' manufactured by Sun Nuclear Corporation, USA. In this internal build up is achieved through the use of differential materials for energies from Co-60 to 25MV accelerator beams .The detector is silicon diode detector. These detectors when coupled with electrometer give high accuracy. These detectors are designed for high sensitivity and stability through the use of integral build up shields. The isorad models cover 3 different energy ranges (1-4 MV, 6-12MV and 15- 25MV). When used in its stated energy range the detector will register the approximate dose equivalent to that at dose maximum point (Dmax). The detector used for the experiment is having energy range 1 –4MV. The detector is cylindrical in configuration (Fig 3) having sensitive volume 0.25mm^3. Output nominal is 1nCoulamb/rad. The cable is having length of 10m and the output polarity is positive. This detector is highly advantageous because of its small size, ruggedness, immediate readout and simplicity of operation.

The dosimeter is positioned at first in the entry point and the instant dose is measured. The diode is positioned in the same place as discussed and the other tangential field is given and the exit dose is measured. The same is repeated every day. The dosimeter is positioned in the central point in the case of supraclavicular treatment and measurements were made at source-surface distance of 80cms. The solid state detector gives dose at Dmax.This measurement is repeated for 15 days for each case for the preset time period.In this study dose calculated at Dmax is compared with the dose measured by the dosimeter.

RESULTS

The average variation of about 2 to 10% is observed in day to day treatment of breast cancer. Especially in the case of tangential fields the variation is found to be more than 5%. In the measurement of dose at Dmax in supraclavicular field, the variation is found to be less than 5%. Exit dose variation is found to be more than the entry dose variation. We can see from (Table I) the variation for the tangential field is positive. On the other hand the variation for supraclavicular field is seen to be negative (Table II).

DISCUSSION

Usually a total variation of 5% (including treatment planning and execution)[5]from the prescribed dose is allowed in the case of radiotherapy treatment. However in the present study the variation is found to be more than 5%.This may be mainly due to inadequacies in the accurate planning. Also a small difference in the patient positioning in day to day set up results in a large dose variation. Therefore the patient positioning and the gantry angle in the setup have a very important role, in the treatment.

A solid-state detector is used for measuring day to day variation in order to get instant reading. The Thermoluminescent dosimeter will not give the instant dose value and also it requires complex procedure for dosemetry. In the case of diode dosemetry daily measurement is simple. The present study highlights the importance of an accurate planning and treatment set up that is necessary for giving exact dose to the patient.

VARIATION OF MEASURED DOSE WITH PRESCRIBED DOSE IN THE CASE OF TANGENTIAL FIELD

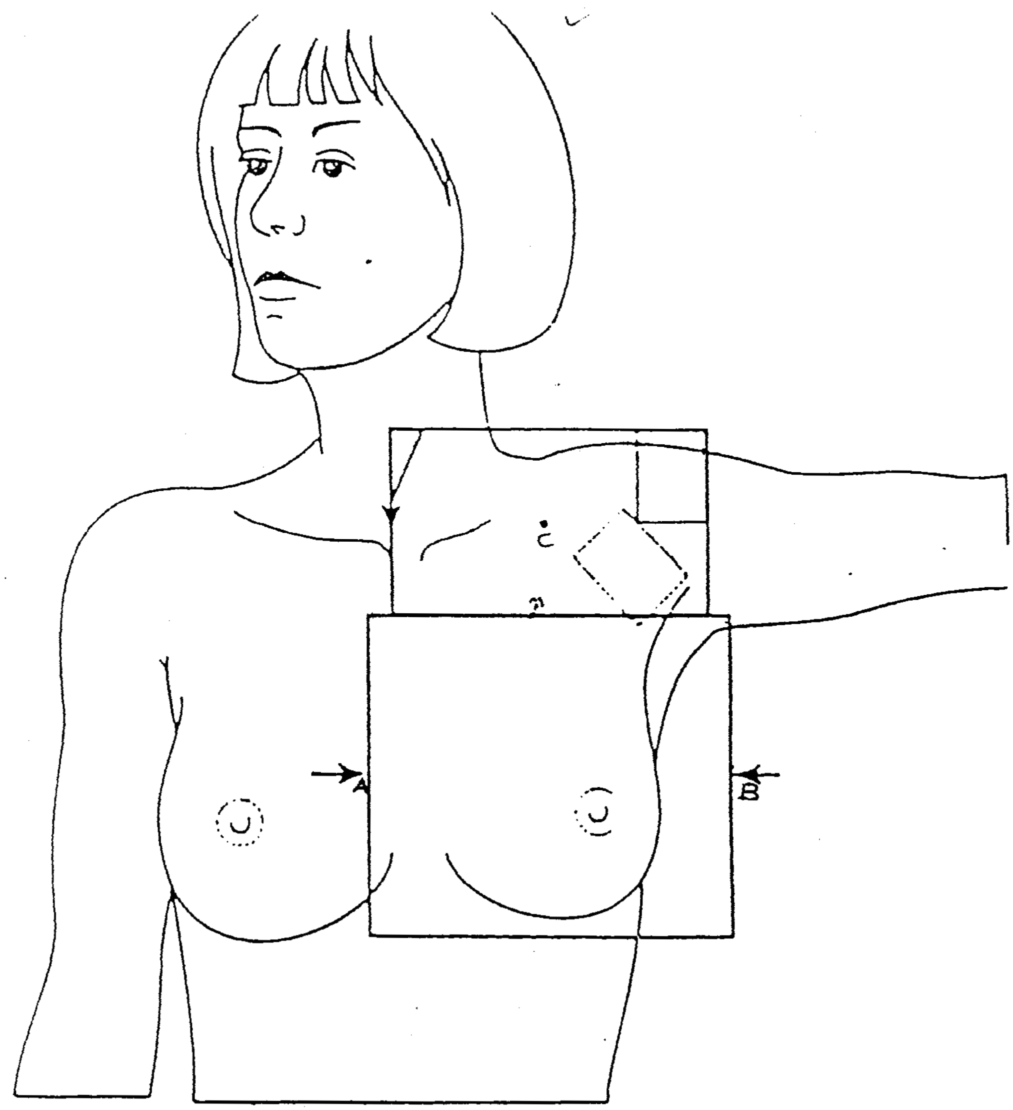
TABLE - 1

Name	Measured dose (entrance dose)	Calculated daily dose(Dose prescribed/no. of fraction/%depth dose	Percentage of Variation
Patient 1	231.7	212	9.3%
Patient 2	197	186	4.8%
Patient 3	159	161	1.2%
Patient 4	198.4	183	8.4%
Patient 5	178	173	2.9%
Patient 6	184.6	176	4.9%
Patient 7	171.4	163	5.2%
Patient 8	201.5	183	10.1%
Patient 9	195	180	8%
Patient 10	179.5	173	3.8%

VARIATION OF MEASURED DOSE WITH PRESCRIBED DOSE IN THE CASE OF SUPRACLAVICULAR FIELD

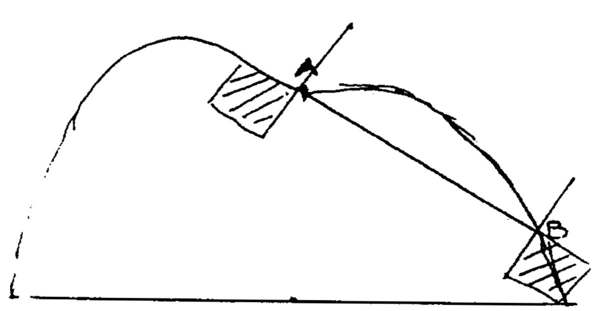
TABLE - II

Name	Measured dose at Dmax	Prescribed dose at Dmax	Percentage of Variation
Patient 1	216.7	225	3.7%
Patient 2	220.75	225	1.9%
Patient 3	218.9	225	2.7%
Patient 4	217	225	3.6%
Patient 5	223	225	0.9%
Patient 6	220	225	2.2%
Patient 7	228.5	225	1.6%
Patient 8	220.5	225	2%
Patient 9	220	225	2.2%
Patient 10	222.75	225	1%



The field arrangement to cover the breast, supraclavicular and axillary nodes.

fig 1

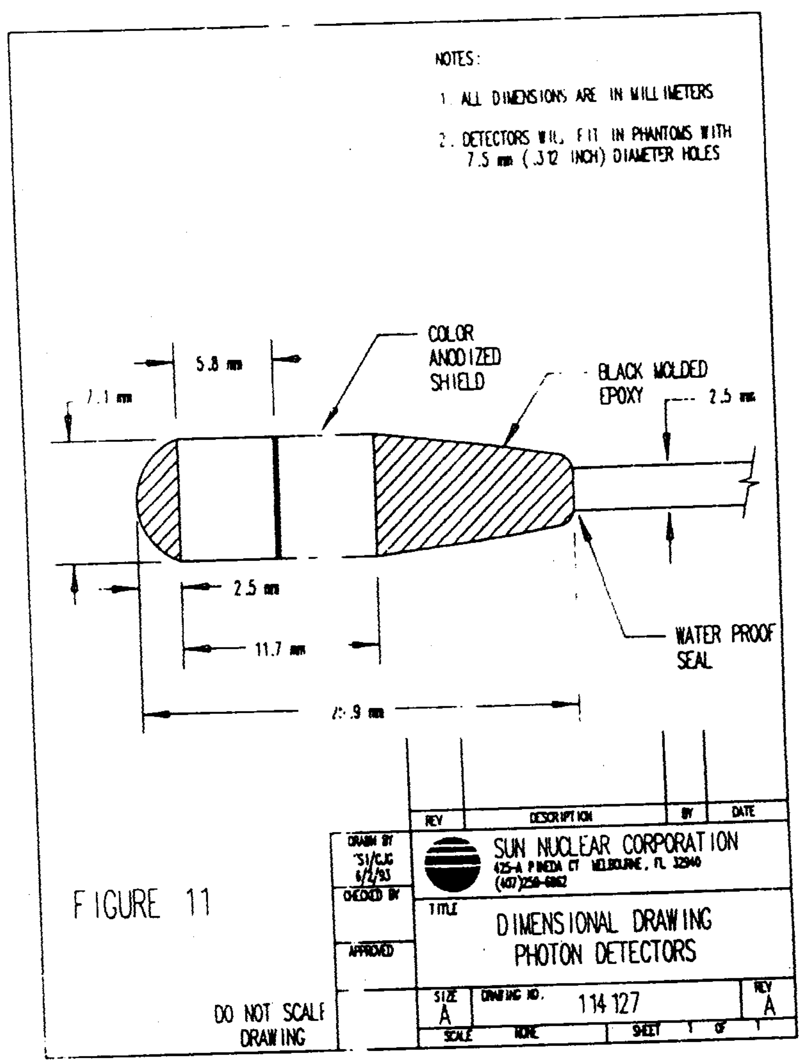


A, B, C shows positioning of the detector

POSITIONING OF DETECTOR

Fig - 2

fig 3


NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETERS
2. DETECTORS WILL FIT IN PHANTOMS WITH 7.5 mm (.312 INCH) DIAMETER HOLES
5.8 mm
7.1 mm
COLOR ANODIZED SHIELD
BLACK MOLDED EPOXY
2.5 mm
2.5 mm
11.7 mm
WATER PROOF SEAL
REV
DESCRIPTION
BY
DATE
DRAWN BY
CHECKED BY
APPROVED
SUN NUCLEAR CORPORATION
TITLE
DIMENSIONAL DRAWING PHOTON DETECTORS
SIZE A
DRAWING NO. 114 127
REV A
SCALE NONE
SHEET 1 OF 1
FIGURE 11
DO NOT SCALE DRAWING

CONCLUSION

The measurement of daily dose is conducted using semiconductor diodes. It is proposed to do further study with Thermoluminescent dosimeters in patients as well as phantoms at various paints. The results will be communicated separately.

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