VERIFICATION OF CALCULATED RADIATION DOSE TO THE "A" AND "B" POSITION OF THE CERVICAL CANCER PATIENTS DURING LOW DOSE RATE (LDR) BRACHYTHERAPY TREATMENT IN BANGLADESH.

M. Phil Thesis

A Dissertation Submitted in Partial Fulfillment of the Requirement for the Degree of Master of Philosophy in Physics

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CONTENTS

ABSTRACT

In oncological unit of Delta Medical Center Ltd., Mirpur, Dhaka, cervical cancer patients are treated with Cs-137 Low Dose Rate (LDR) Brachytherapy with combination of external beam therapy. In our study, absorbed radiation dose was calculated for 18 patients at point A, point B, bladder reference point and rectum reference point in case of brachytherapy treatment. The calculated 'A' point and 'B' point dose was verified with the radiation dose to the respective point supplied by the suppliers. The percentage variation at point A was found to be – 9.5% to + 10%, which is comparable with the international standard (within ± 10%). The percentage variation at point B was found to be –8.59 % to + 8.23 %, which is also comparable with the international standard. The bladder dose was found to vary from 786 cGy to 4439 cGy, which is 29% to 180% of calculated dose at point A. The rectum dose was found to vary from 882 cGy to 2759 cGy, which is 24% to 103% of the calculated dose at point A.

Chapter I
INTRODUCTION

Cancer is one of the most fearsome diseases man has ever known. Surgery, radiotherapy and systemic chemotherapy remain the basis of the management of patients with cancer. Radiotherapy is the technique of therapeutic treatment with the use of ionizing radiation. The technique is primarily used for the treatment of cancer. Every year more than nine million additional people globally are affected by cancer. About 50% of these patients need radiotherapy. The incidence rate of cancer increases as the age increases. It is estimated that by the year 2015 the global cancer incidence rate will increase to 15 million per year and two third of these patients will belong to the developing countries[1] like Bangladesh.

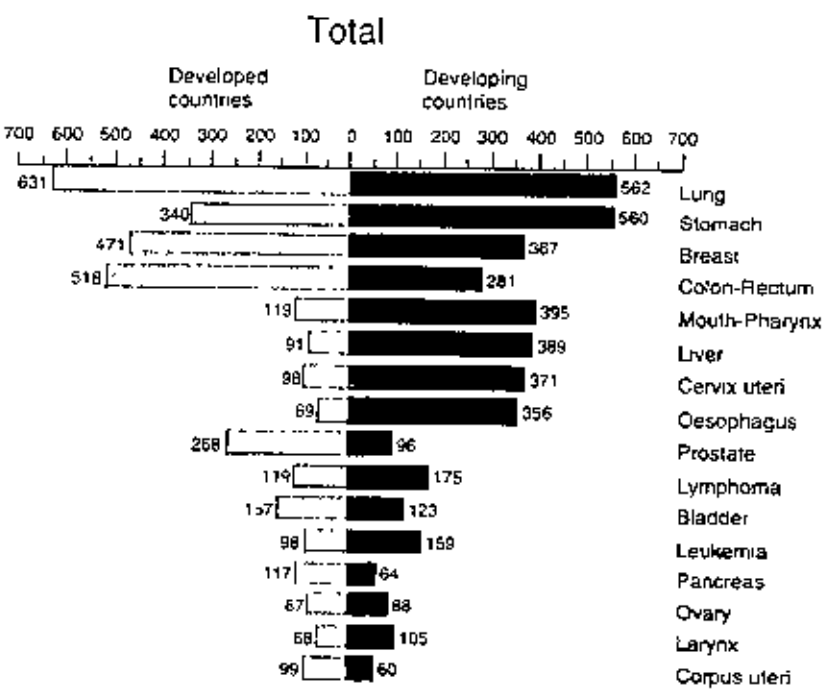


Fig.1[2]**:** Worldwide distribution of cancer types 1990, ranked by total number of cases for various diagnoses.

The distribution of cancer cases between the sexes worldwide is fairly even 4.77 million cases occurring in males and 4.55 million cases in females. Since the incidence of cancer increases by age, the majority of new cases occur in the age group 65+ years. The age distribution of cancer is, however, quite different in developed and developing countries; there are significantly more cancer cases in childhood, adolescence and young ages in the developing countries, while cancer in the elderly still dominates in developed countries[2].

Radiotherapy started with the use of Radium, soon after its discovery by Madam Marie Curie in 1898. But the use of Radium has been banned several decades ago due to the risks and detriments it caused to the doctors and the public. Now gamma radiation using teletherapy units (Co-60), Brachytherapy (Cs-137, Ir-192, Au-198) I-125 etc), electrons & photons emitted by linear accelerators, radio-pharmaceuticals and even neutrons produced by specialized reactors are used for radiotherapy.

Cells are the building blocks of the human body. Each body tissue and body organ is made up of billions of cells that work together so that each body system can function in a normal, useful way. Certain illnesses, such as cancer, begin because changes occur in the cells of the body that cause them to act in an abnormal way. Cancer cells are not normal cells, therefore, they do not function as they should. They serve no useful purpose in the human body.

There are many different kinds of cancer and each behaves in a slightly different way. Radiation therapy is one of several methods used in cancer treatment. Radiation therapy attempts to destroy the abnormal cancer cells that are present in a particular part of the body. It can be used alone in the treatment of some cancers or in combination with surgery and/or chemotherapy. Regardless of the method used, the purpose of all cancer treatment is to rapidly destroy the cancer cells that are present in the body.

There is high incidence of lung cancer (34%), larynx cancer (24%) in males and cervical cancer (37%), breast cancer (29%) in females in our country[3]. In case of

cervical cancer, low dose rate (LDR) brachytherapy is an integral part of the treatment.

Brachytherapy is a method of treatment in which sealed radioactive sources are used to deliver radiation at a short distance by interstitial, intracavitary, intraluminal or surface applicator. With this mode of therapy, a radiation dose can be delivered locally to the tumor with a rapid dose fall off in the surrounding normal tissue[4]. Intracavitary therapy is most widely used for cancers of uterine cervix, uterus and vagina. The radiation treatment is usually fractionated that is given in a series of daily doses spread over a number of weeks, resulting in better therapeutic ratio for most tumors than giving the treatment as a single dose. When radiation treatment is fractionated, it is found that a much greater total dose is required to achieve a given level of biological damage than when a single dose is used. This indicates that recovery from radiation damage occurs between fractions. This recovery is a complex process involving repair of damage by individual cells and the effects of cell growth during the fractionated course of treatment.

The four factors that may influence the effect of such fractionated treatment are, repair of sub lethal damage, repopulation by surviving cells in the irradiated tissues, redistribution of cells throughout the division cycle, and reoxygenation of hypoxic cells, primarily in tumors[5].

In our country cervical cancer is treated using Manchester system and the dose is delivered through Fletcher-suit applicator[6,7], which basically consists of a central tube, called the "tandem" and the lateral capsules or "ovoids". The ovoids are separated from each other by the spacer. The Manchester system is one of the oldest and most extensively used systems in the developing countries where the computer planning is not available. It is characterized by doses to four points[4], viz. point A, point B, a bladder point and a rectum point. The duration of the implant is based on the dose rate calculated at point A. Point A is defined as 2 cm superior to the external cervical OS, and 2 cm lateral to the cervical canal. Point B is defined as 3 cm lateral to point A.

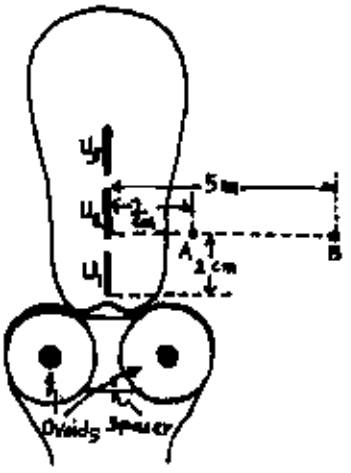


Fig.2[5] : Schematic diagram of the uterus showing the use of intrauterine tubes and ovoids in the treatment of cancer of the uterus.

In radiotherapy the exposed person is the direct recipient of an intended benefit that can be compared with the potential risk to that same individual, and the exposure is voluntary. Most radiation exposures should be limited to doses as low as reasonably achievable, but in radiotherapy the dose should at least be high enough to eradicate the malignant cells. Here the radiation is the curing agent and according to the principles of this discipline, a dose as high as reasonable achievable (AHARA)[8] limited only by the likelihood of concurrent complications, should be administered to the treated volume For this purpose, it is necessary to calculate the absorbed dose at point A and B and the most critical organs (viz, rectum and bladder). The A and B point doses will be compared with the radiation doses to the respective points supplied by the suppliers.

Chapter II
REVIEW OF PAST WORKS

Review of Past Works

A method for calculating optimum irradiation conditions, with the doses predefined at selected points on an optimum isodose curve, was developed by K. Tabushi, M. Sakura et al.[9] of Japan for intracavitary radiotherapy using quadratic programming[10]. This calculation system is applicable to a remote controlled afterloading therapy for carcinoma of the uterine cervix, the bile duct and the oesophagus. In the case of carcinoma of the uterine cervix, an automated calculation system for conventional intracavitary radiotherapy was devised. Reference was made to an isodose curve, which passes through points A of the Manchester system; this was represented by high order polynomials using polar co-ordinates to carry out the therapy.

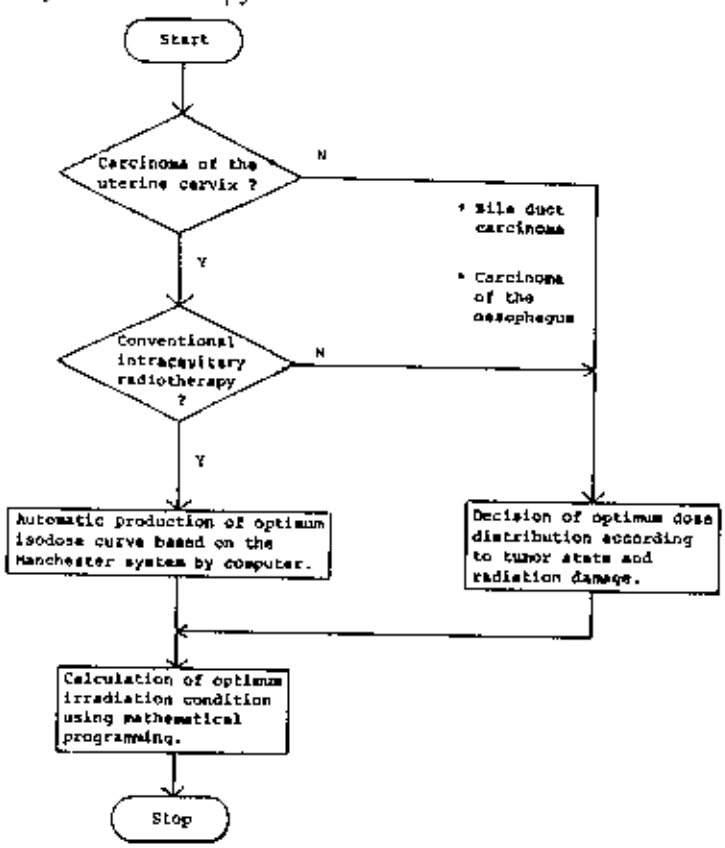


Fig 2.1: Flow chart of optimum treatment planning for intracavitary radiotherapy using mathematical programming.

To achieve brachytherapy efficiency in the clinical routine, some quality assurance procedures were developed by Di Nallo. A. M.,[11] et al of, Rome, Italy to control the distribution algorithm and the nominal parameters of Cs-137 low dose rate sources. Experimental methods, based on the dose measurements in air, water and perspex phantom by means of TLD-100 LiF and ionization chamber. The source characterization is obtained by means of an optimization process to evaluate a physical parameter involved in the theoretical algorithm, and the dose measurement in a well-defined point.

The radiation dose distribution of external and intracavitary therapy in different points and organs of 50 patients with carcinoma of the uterine cervix in Alexandria University Hospital, Egypt, were computed by El-masry et al[12]. The extent of the tumour and the position of critical neighboring organs were determined for clinical dosimetry. The treatment protocol consisted of: (a) whole pelvic external Cobalt-60 radiotherapy and manual afterloading radium application and / or (c) parametrial boost dose of external Co-60.

Table2.1: Mean dose rate computed at different anatomic points in optimal geometrical position

Anatomic site	Dose rate (cGy h^{-1})
External os	185.4±7.5
Vaginal vault	164.6±5.5
Uterine wall	96.5±9.3
Point A	43.5±6.4
Point B	16.6±8.1
Urinary bladder	22.1±8.2
Rectum	26.8±6.7

The dose rates at point B did not exceed 30 – 40% of the dose at point A. the mean rectal dose rate was 26.8±6.7cGy h^{-1}.

Jones C.H.,[13] et al measured staff exposure doses in case of low dose rate brachytherapy techniques. They had investigated the role of the different types of dosimeters used for measuring staff exposure doses including film monitors, TLD dosimeters and PENDIX personal dosimeters

Table 2.2: Radiation doses (μSv per insertion)

	Traditional	Manual afterloading	Automatic afterloading
Cs-137 handlers	40	10	–
Radiotherapist and assistant	180	20	–
Theatre nurses	80	–	–
Ward nurses	225	200	10
Additional staff	50	–	10
Total dose(μSv /80 mg Ra eq Cs-137 insertion)	575	230	20

Table 2.2 summarizes the results of radiation exposures received by all staffs involved in treating and caring for patients receiving gynecological intracavitary radiotherapy caesium techniques.

Petoussi, N[14]et al calculated the organ doses from radiotherapy for cervical cancer patients. It was a part of large radiation study supported by the WHO and involved the follow-up of 30,000 women treated for primary cervical cancer and the measurement of the incidence of secondary cancers. In order to calculate the organ and tissue doses a Monte carlo program was used which simulates the scattering and absorption of photons within a three dimensional anthropomorphic female phantom, based on a reference woman with all female organs[15].

Calculations were performed to estimate the absorbed doses to various organs resulting from intracavitary sources such as ovoids and applicators filled or loaded with Radium, Co-60, Cs-137. Calculations were made also for external beam therapy.

Thirty-six Tables were compiled[16] containing the doses for 106 organs and tissues 12 for internal therapy and 24 for external therapy arrangements. As an example, Table 2.3 shows some organ doses for three of the cases including the follow-up study of the WHO.

Table 2.3: Organ doses

Organ	Case1 brachytherapy Only (cGy)	Case2 single ovoid+external AP + PA fields (cGy)	Case3 Ovoids, applicators + split AP + PA fields (cGy)
Bladder	4515	5547	8334
Breast	18	5	21
Kidneys	139	47	160
Liver	80	26	94
Lungs	22	6	25
Ovaries	2387	4298	5300
Rectum	1732	1767	2900
Peak dose (skin)	941	8202	6700
Point B	4677	5268	8200
RBM(total)	370	333	550
RM pelvis	909	880	1490
Small intestine	770	314	947
Stomach wall	107	35	122
Thyroid	3	0.8	3.5
Total body	417	370	662

Objectives of the Present Study

In our country, the regular medical check-up of the people is not frequent because of their low level of income. Also the people are not so conscious about their health care. So most of the patients with cancer of the uterine cervix are first seen in relatively advanced stages of the disease with prevailing local infection.

Radiotherapy plays a major role in the management of patients with carcinoma of the uterine cervix. Brachytherapy is a dominant element in the care of early stages, while additional external irradiation is necessary in advanced stages [17].

If the application geometry is properly combined with well-fixed dose prescription, the results are excellent, both as regards high cure rate and good tolerance of normal tissues. The best results can only be obtained when there is a good teamwork between gynecologists, radiotherapists, physicists and others with a particular interest and experience.

Treatment of cervix cancer patients are being done by wedge shaped mid lined block in TMC (Tata Memorial Centre), Mumbai, India. In private sector, Delta Medical Centre Ltd. has fabricated a wedge shaped mid lined block and which are used for the treatment of cervical cancer patients (both pre-operative and post operative case.). The irradiation consists of AP/ PA external beam delivering 50Gy in 25 fractions over 5 weeks period, 5 fractions per week (10Gy open field[18] and 40Gy is given using wedge shaped mid line block) and two intracavitary insertions is usually prescribed for radical treatment.

The applicator supplied by Bhaba Atomic Energy Centre, Mumbai, India, consists of one intra-uterine tandem, which is placed in the uterine canal, and two vaginal ovoids, which are placed against the cervix. There are two types of intra-uterine tandem tubes[19] :

1. Long intrauterine tubes contain 3 sources of activity; 120 mCi, 80 mCi and 80 mCi respectively.
2. Medium intrauterine tubes contains 2 sources of activity; 120 mCi, 80 mCi respectively.

And the two ovoid contain the 4 sources of activity 40 mCi each.

Ideally, a point A represents the location where the uterine vessels cross the ureter. It is believed that the tolerance of these structure is the main limiting factor in the irradiation of the uterine cervix.[4] In addition , it is useful to know the dose at point 'B', on the pelvic wall opposite point 'A'. Most experienced therapists feel that whatever other dose calculations are made, the dose at point A and B should be known in every case treated by a particular geometric arrangement[5].

To achieve maximum tumour control and to avoid complications a study of the dose calculation at point 'A' and 'B' and to verify the calculated dose with supplier's data and the corresponding bladder and rectum dose calculation is essential. To achieve these objectives the absorbed dose of 18 patients was calculated.

Chapter III
BIOLOGICAL EFFECTS OF RADIATION

Biological Effects of Radiation

When ionizing energy is absorbed by living tissue, biological effects are to be anticipated. These may cause produce profound changes in the tissue resulting either in immediate damage to or deaths of cells or through genetic alternation may manifest themselves only in subsequent generations.

3.1 Mechanisms of Biological Action

The biological effects of the higher – energy electromagnetic radiations and of all the particulate radiations are mediated through the ionization (and, to a lesser extent, the excitation) that they produce in biological tissue. An explanation of its modes of action must be sought at the cellular level; effects on the whole organisms are likely to be secondary. Two main types of intracellular action have been distinguished: first, direct action through ionization of biological structures along the ionized track; and second, indirect action through the formation of radioactive chemical fragments (free radicals) that diffuse away from the ionized track and undergo further reaction elsewhere.

Direct Action: direct biological actions were studied in great detail in the period between 1927 and 1947. A detailed quantitative theory was elaborated, the "target theory", whereby a tissue undergoing irradiation was likened to a field traversed by the fire of a machinegun. It was supposed that, to produce a given effect, there must be one or more hits by an ionized track on a sensitive target, so that the probability of obtaining the effect was dependent on the probability of obtaining the requisite number of hits on the appropriate target. This theory was very successful in giving a quantitative treatment of many of the biological effects of radiations, particularly in the field of genetics.

Indirect Action: In the field of radiation chemistry, where free radicals produced by radiation play a vital role as intermediates in chemical reactions, the target theory had little application, and from about 1940, the interest of radiation biologist tended to shift towards the indirect actions of radiations. This shift was given

impetus by the discovery in 1947 that the induction of chromosome breakage, which has until been viewed as a target effect per excellence, was enhanced if the oxygen was increased in the material irradiated.

Radiolysis of water results in the formation of numerous species of radicals, including hydrogen and hydroxyl radicals. In the presence of molecular oxygen, the peroxyl radical will be formed, and the effectiveness of the radiation in producing biological damage will be increased. This is the basis of the oxygen effect used advantageously in radiotherapy.

3.2 Adverse Radiation Effects

Adverse radiation effects are usually divided into two categories: stochastic and deterministic effects. **Stochastic effects** - most commonly refers to the radiation induction of neoplasm's or hereditary effects. These effects are due to unrepaired or mistepaired DNA damage. The probability of incurring these effects is a direct function of dose and there is no known threshold below which these effects do not occur. However, at low doses the probability of the effects may be so small as to be impossible to find using epidemiological or population studies. The severity of stochastic effects is dose independent. Epidemiological studies have shown that the mean latent period, the time from exposure to clinical appearance, is 7 – 10 years for leukemia and about 20 years for solid tumours[20,21].

Deterministic effects are mostly due to cell killing. If only a few cells in a given tissue are killed, no effect will be apparent. If enough cells are killed, there will be an obvious clinical effect. An example of a deterministic effect is skin necrosis. Thus for deterministic effects there is a threshold below which the clinical effect will not be apparent, and the severity of a deterministic effect is a direct function of dose[22].

3.2.1 DNA Damage by Ionizing Radiation:

The gene component, DNA is a pair of linear long chain-like, molecules called polynucleotides, wrapped around one-another as a spiral ladder shaped double helix complex molecule composed of two chains or strands, wound around each other. This complex molecule comprises numerous individual units or nucleotides. Nucleotides are made of four types of complementary bases called adenine,

guanine, thiamine and cytosine. The sequences of the bases express the genetic codes[23]. By the action of chemical radicals, ionizing radiation can directly or indirectly induce changes in the sequence of bases and therefore alter the genetic codes. This process is known as mutation or DNA damage, which if not repaired, induced cellular derangement's as well as inhibition of DNA replication and can alter the information that passes from a cell to its progeny[24]. Gene mutations are proportional to the amount of energy absorbed and their effects are cumulative in successive generations in a restricted sense, i.e. during the reproductive period of life, most radiation-induced gene mutations are believed to be recessive and deleterious.

3.3 Radiation Risks from External Radiotherapy and Brachytherapy

Radiotherapy has been predominantly used to treat malignancies but it also is occasionally used to treat benign diseases. Adverse effects from radiotherapy can occur both early and late as a result of deterministic effects. As a result of extensive clinical experience, radiotherapists have constructed tables of the tolerance dose of different tissues. They also have experience regarding what dose is required for disease control Combination of these two parameters results in a prescribed dose and treatment schedule. The prescribed dose is usually in a fairly narrow range since normal tissue tolerance and cancer radiosensitivity are not very different. Doses less than the correct prescribed dose will result in few complications but also few cures. Higher doses will result in an unacceptably high rate of severe complications. In addition to adverse deterministic effects, if the patients survive more than several years, there is an increased risk of radiogenic tumours in and around the treatment area[22].

3.4 Radiation Induced Carcinogenesis[25]

The possible mechanism of action of radiation induced carcinogenesis is briefly presented in Fig- 3.4

In the cell nucleus, within a second of radiation exposure, various free radicals are formed and will react with important biological macromolecules, e.g., DNA or chromosome proteins, to produce many types of lesions. Within minutes to hours,

lesions will be either correctly repaired or misrepaired through enzymatic or non-enzymatic processes. An alteration of DNA or nuclear protein or both due to misrepair can cause some genetic and epigenetic effects. These effects may directly (or indirectly through an activation of viral information) initiate the neoplastic cell transformation. After weeks of proliferation, cell with transformation lesions express properties of cancer cells. Some transformed cell will be selected by various physiological and immunological factors to develop into cancer. Consequently the entire process of cancer development may take many years.

Possible Mechanisms of Action of Radiation - induced carcinogenesis :

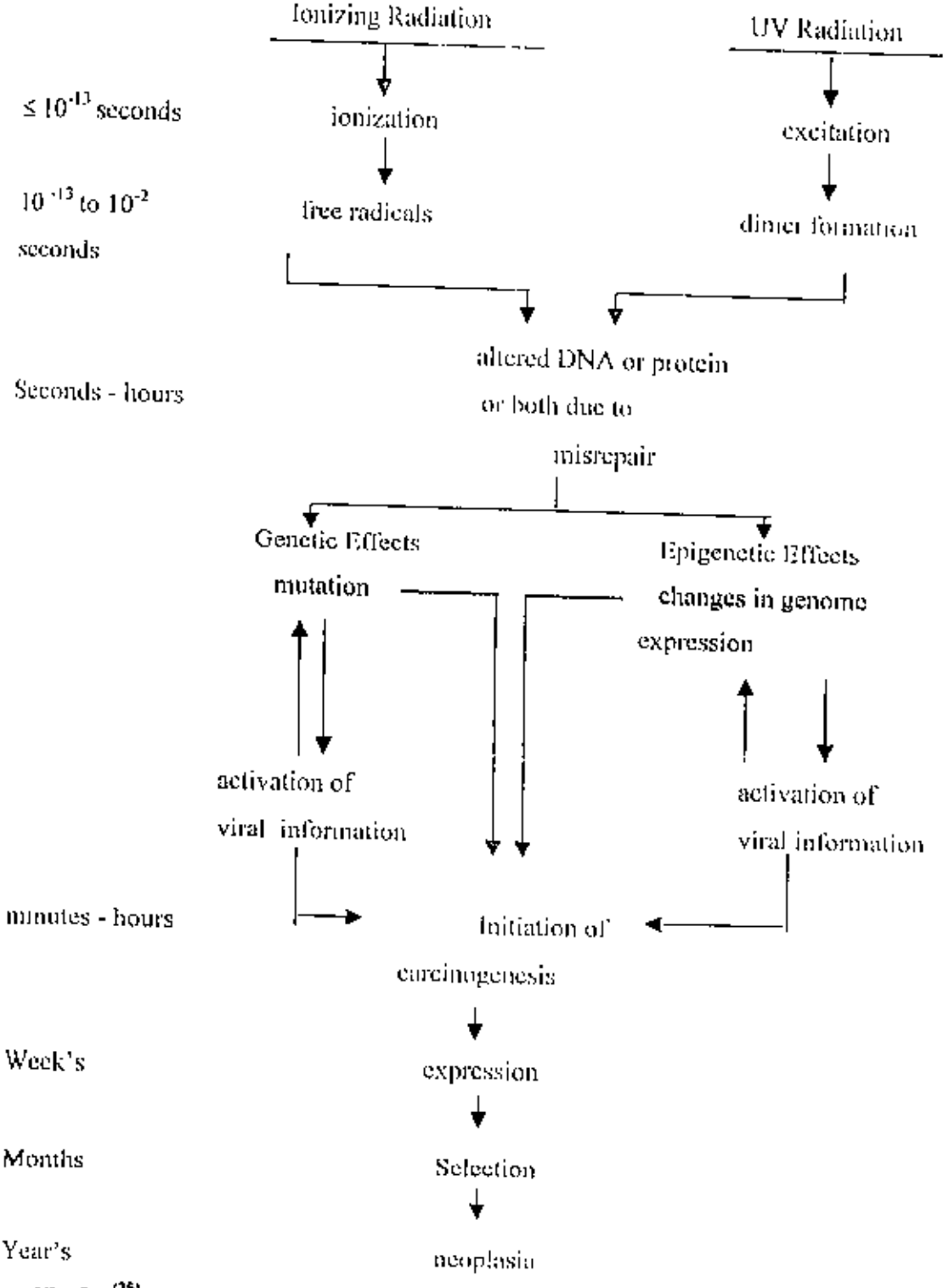


Fig 3.4[25]: A simplified diagram showing the possible mechanisms of action of radiation in carcinogenesis. The time scale is provided only for approximation.

Chapter IV
PRINCIPLE OF RADIOTHERAPY

4.1. Physical Basis of Radiotherapy

All radiations of value in radiotherapy produce damage in target tissues or tumours by virtue of their capability to cause ionization within the target volume [26-28]. The creation of ionization is a property of electromagnetic radiations of very short wavelength. Electromagnetic radiation consists of X- rays and gamma – rays. They differ only in the way in which they are produced. γ- rays are produced intranuclearly and X- rays are produced extranuclearly. In practice, this means that γ- rays used in radiotherapy are produced by the decay of radioactive isotopes and that almost all the X- rays for both diagnostic and therapeutic purposes are usually produced by the deceleration of electrons in a metal target (usually tungsten because of its high atomic number). The intensity of electromagnetic radiation dissipates as the inverse square law of the distance from the source.

The relative prevalence of the three dominant absorption mechanisms of electromagnetic radiation depend on energy of the radiation.[27] The first is **photoelectric absorption**, which is predominant at lower energies. In this circumstance the photon interaction results in the ejection of a tightly bound orbital electron. Photoelectric absorption varies with the cube of the atomic number (Z^3). This has significant practical implications because it explains why materials with high atomic numbers, such as lead, are such effective shielding materials. The second type of radiation absorption is the **Compton type**. In this process, the photon interaction is with a distant orbital electron that has a low binding energy. In this process the photon does not give up all its energy to a single electron, an appreciable portion reappears as a secondary photon, which is created in the interaction. The probability of Compton absorption does not depend much on atomic number, but rather on electron density. This explains why films made at supervoltage energy do not show much difference between bone and soft tissue, but air cavities are clearly distinguished. The third type of absorption is the **pair**

production process. This type of absorption requires incident photon energy greater than 1.02 MeV. In this process positive and negative electrons are produced at the same time.

The fundamental quantity necessary to describe the interaction of radiation with matter is the amount of energy absorbed per unit mass; this quantity is called **absorbed dose** and the 'rad' was the most commonly used unit. Absorbed dose is measured in Joules per kilogram; 1 Joule/ kg = 1 Gray (1 Gray = 100 rad), which is now the recommended unit.

The different ranges of electromagnetic radiations used in clinical practice are **superficial** radiation or roentgen rays from about 10 to 125 keV; orthovoltage radiation or electromagnetic radiation between 125 to 400 keV; and supervoltage or Megavoltage radiation for energies above 400 keV. As energy increases, the penetration of the roentgen rays increases (fig 1), and at supervoltage energies, absorption in bone is not higher than that in surrounding soft tissues, as in the case with lower energies. This is because at supervoltage energies, Compton absorption predominates. Compared with orthovoltage, supervoltage radiation is skin sparing, meaning that the maximum dose is not reached in the skin, but instead occurs below the surface. The electrons created in the interaction travel some distance and do not attain full intensity until they reach some depth, resulting in a reduced dose to the skin. For this reason, for the treatment of deep – seated malignant tumours cobalt therapy is used employing high energy gamma rays (viz, 1.17 MeV and 1.33 MeV so as to deliver an average energy of 1.25MeV per disintegration) for Co-60 source.

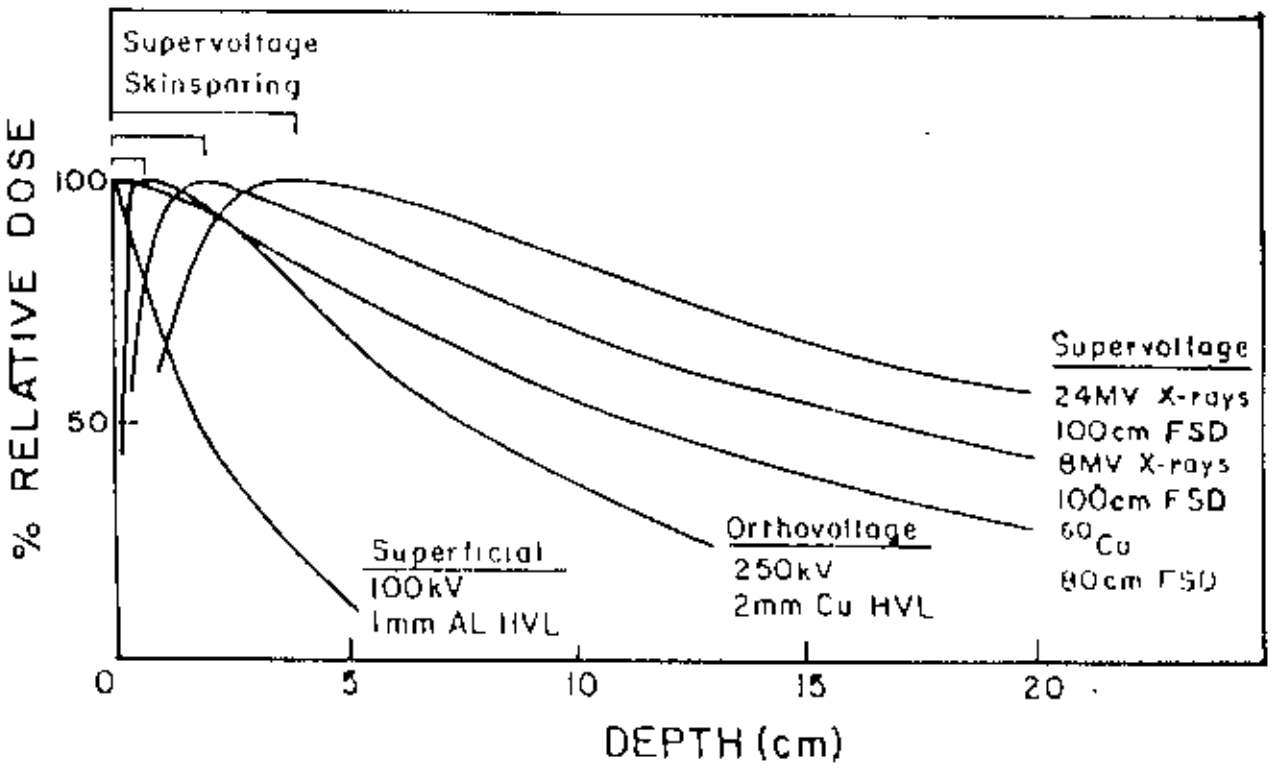


Fig 4.1 [27]: Relative dose at different depths for various types of ionizing radiation.

4.2 Radiation Techniques:

Two general types of radiation techniques are used clinically – brachytherapy and teletherapy (external beam therapy).

4.2.1 Brachytherapy[29]

Brachytherapy is a radiation therapy modality that allows the escalation of radiation dose while sparing normal tissues. Increased radiation dose has been shown in many situations to provide improved results by improving local tumor control. Brachytherapy involves the placement of radioactive sources ("seeds" or wires) either in tumors (**interstitial implants**) or near tumors (**intracavitary therapy** and **mold therapy**). The radiation is emitted outward, unlike external beam radiotherapy, where radiation must traverse normal tissue in order to reach the tumor. The word "brachytherapy" means "short therapy", appropriately implying that the radiation is limited to short distances. This results in decreased toxicity and/or allows the escalation of radiation dose. Brachytherapy can be used intraoperatively in situations where surgery is not possible or not optimal or in situations where prior dose-limiting external radiotherapy has already been given. Combined approaches of surgery and brachytherapy can often improve the results of surgery alone in a variety of malignancies. Common applications include the **endoluminal** treatment of recurrent endobronchial and bile duct tumors, the **intracavitary** treatment of cervical and endometrial cancer, and **interstitial implants** in unresectable tumors with catheters or radioactive seeds Occasionally, hyperthermia will be combined with either brachytherapy or external beam irradiation to relieve pain and other symptoms of recurrent disease originating from head and neck or breast cancers.

4.2.2 Teletherapy

Teletherapy uses a device located at a distance from the patient, as in the case in most orthovoltage or supervoltage machines. Typical teletherapy isodose distributions are shown in fig - 4.2. The dose depends on inverse –square considerations and tissue absorption. The distribution of radiation depends on

characteristics of the machine and the patient. The isodose curve depends on the energy of the radiation, the distance from the source of radiation, and the density and atomic number of the absorbing material. The beam of radiation produced in typical radiation treatment may be modified to make isodose distributions confirmed to the specific target volume, and individually designed shields are used to protect vital normal tissues. The most commonly used beam modifying device is the wedge – filter[30]. Wedge filters are placed in the path of a beam to modify its isodose distribution.

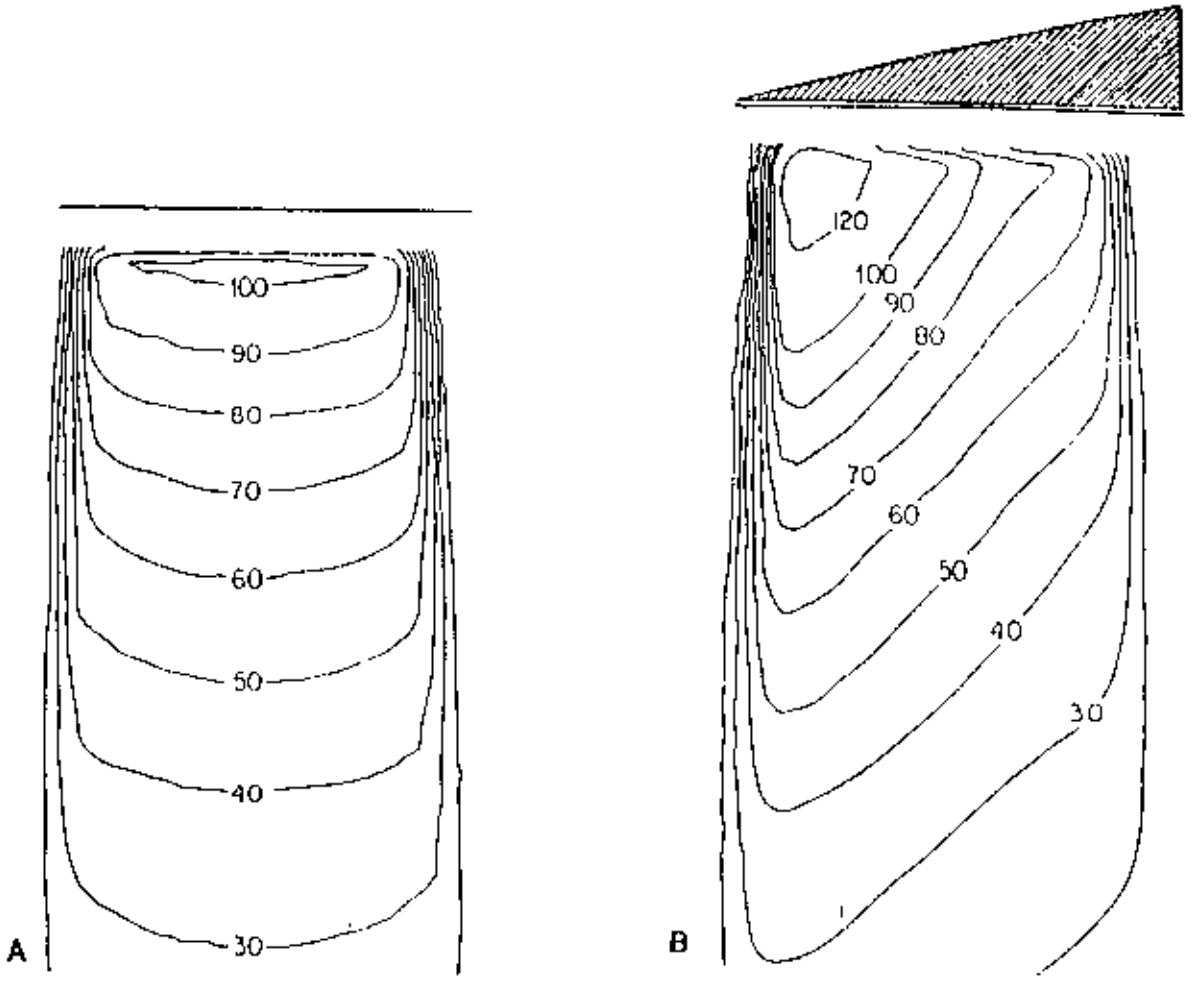
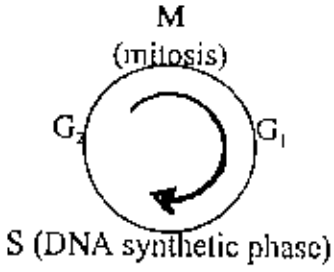


Fig 4.2 [27] Typical teletherapy isodose distributions (A) Without a wedge filter (B) With a wedge filter .

4.3 Biological Basis of Radiotherapy

4.3.1 The Ccell Cycle and Radiosensitivity[31-32]:

Mammalian cells reproduce by the process of mitosis (see Fig – 4.3.1). During mitotic division, the chromosomes in the nucleus of the cell divide; the nucleus splits into two daughter cells, each of which carries a chromosome complement identical to that of the parent cell. After an interval of time each of the daughter cells may undergo further mitotic division. The time interval between successive divisions is the "cell cycle time". The cell cycle can be divided into four phases: G_1,S,G_2 and M. It is found that generally the mitotic phase (M) is most radiosensitive, and G_2 almost as sensitive. That is, injury is most likely to occur during the mitotic phase of the cycle or during the G_2 phase when the quantity of DNA is double in preparation for mitosis. Fig 4.3 represents schematically the cell cycle time of mammalian cells.



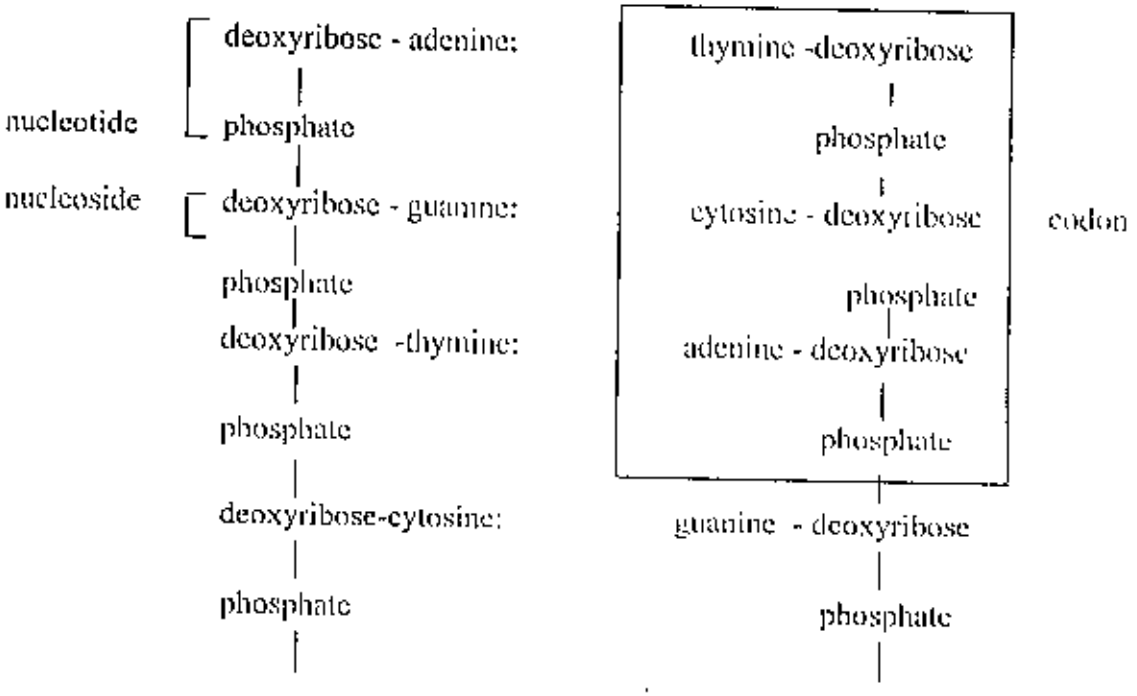
M = mitotic phase;

G_1 and G_2 = resting phases;

S= the phase when DNA is synthesised.

Fig 4.3 Cell cycle time

DNA is a highly complex molecule, which contains the genetic information for particular cell. It forms the essential part of the chromosome structure, and therefore the quantity of DNA in the nucleus has to be doubled prior to mitosis. Chemically the DNA molecule is relatively simple. There are four bases, adenine (A), guanine (G), cytosine (C), and thiamine (T). Each is attached to a simple sugar deoxyribose (making a nucleoside) and this, in turn, to phosphate. The base –sugar-phosphate unit is called a nucleotide. Watson and Crick (1953) showed that two basis could bind to each other across the two strands of the double helix. The bases pair specifically A – T or T – A and G- C or C – G



Three bases on one of the strands constitute the coding unit. This after conversion in an RNA nucleotide sequence, codes for each amino acid in each and every protein. When the DNA is to be duplicated the two strands separate and at the same time specific enzymes in the nucleus take the individual precursor nucleotides and attach them to each other and they attach base: base to the parent strand to make an exact replica on each. In fact the two daughter cells each have one strand of the parental DNA. It is the sequence of these links which constitutes the genetic code and which is faithfully reproduced at each cell division DNA is usually assumed as the critical target for radiation effect.

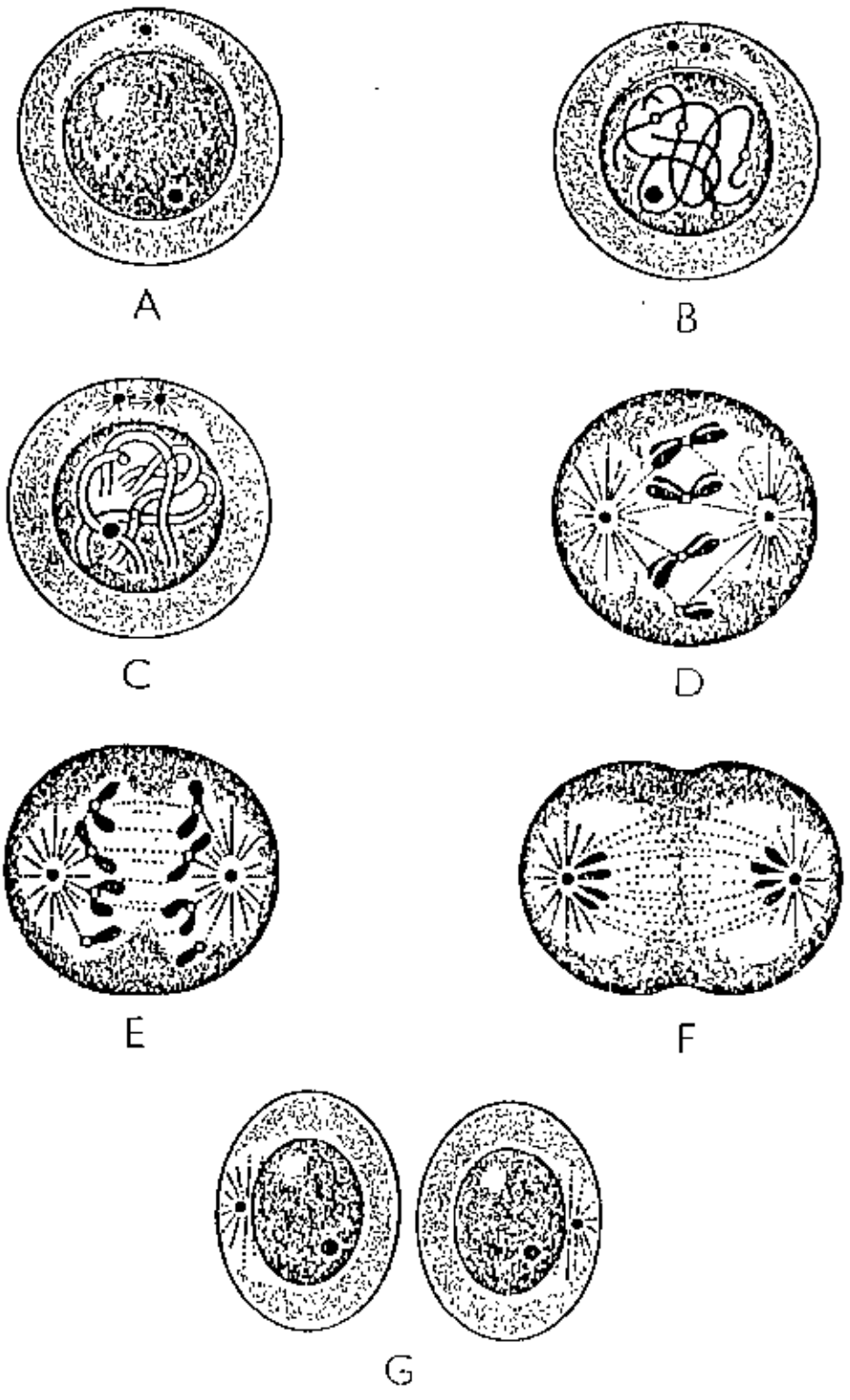


Fig 4.4[32] : Typical diagram of mitosis process.

(a) interphase; (b) Early prophase; (c) Mid-prophase(each chromosome has doubled); (d) Metaphase; (e) Anaphase; (f) Telophase; (g) Daughter cells

4.3.2 Oxygen Effect [5,33]

The presence of Oxygen at the time of irradiation acts as a sensitizing agent; the biological effects of the radiation are greater in the presence of oxygen than in its absence. The oxygen enhancement ratio (OER) is a conventional parameter to describe the oxygen effect. OER is the ratio of dose required for equivalent cell killing in absence of oxygen compared with the dose required in the presence of oxygen. The OER range for different cells that have studied varies from about 2.5 to 3.5, this means that cells irradiated in the presence of oxygen are about 3 times as sensitive as cells irradiated under conditions of severe hypoxia (very low level of O_2).

The oxygen effect is extremely important in radiotherapy because tumours may contain a significant fraction of clonogenic cells, which exist at oxygen tensions low enough to provide full hypoxic radioprotection. In tumours the blood vessels are often poorly formed leading to regions that have an inadequate supply of oxygen.

Thomilson and Gray recognized the importance of the oxygen effect in a classic paper in which they showed that tumours from humans frequently had anoxic regions. Calculations of oxygen diffusion from capillaries and metabolism predicted that the oxygen tension would decrease to zero at a distance of about 150μm from the capillary. Those cells within about 100μm of the capillary are well oxygenated; those beyond 150μm are anoxic and necrotic; and those between 100 and 150μm are hypoxic at an oxygen tension that might protect cells from radiation. Diagrammatic representation of a tumour by Thomlison and Gray is shown in Fig 4.5

If hypoxic (radioresistant) cells develop because of oxygen diffusion limitations than increasing the partial pressure of O_2 in the blood should result in greater diffusion, and hence better oxygenation of the hypoxic cells.

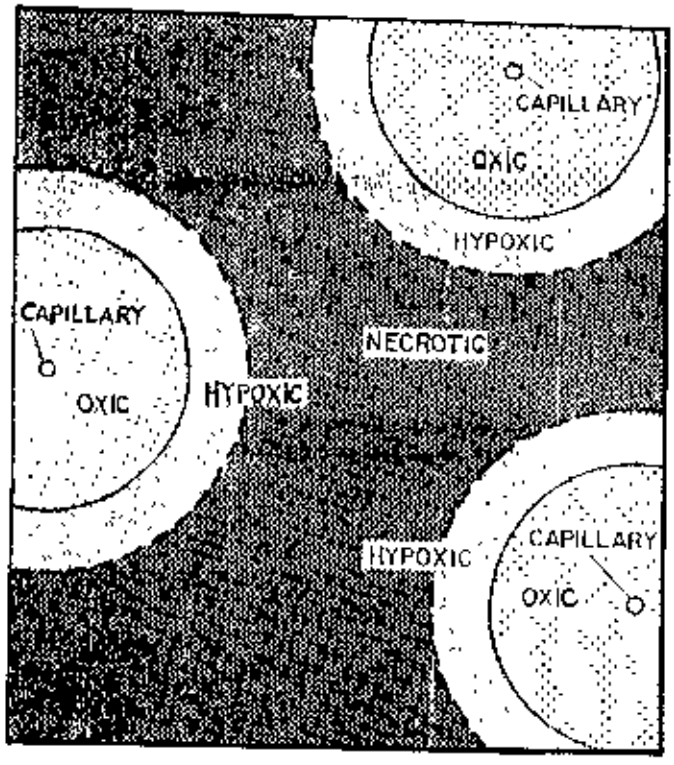


Fig 4.5 [27]: Diagrammatic representation of a tumour.

4.3.3 Relative Biologic Effectiveness

Relative biologic effectiveness (RBE) is a commonly used parameter in radiation biology. It is the dose ratio of different average LET beams required to produce the same biologic effect. High LET radiation differs from low LET radiation in affecting the shoulder and the slop of the radiation survival curves. The RBE and OER change with LET. The RBE increases with LET reaching a maximum around 100 kev /µm and decreases with further increase in LET due to saturation at higher LET values. The OER decreases as the LET increases and reaching unity at around 100 kev /µm (Fig – 4.6). With very high LET radiation, there is a fall in RBE because this very densely ionizing radiations deposit more than one lethal event per cell. Some of the absorbed dose is redundant and become less efficient.

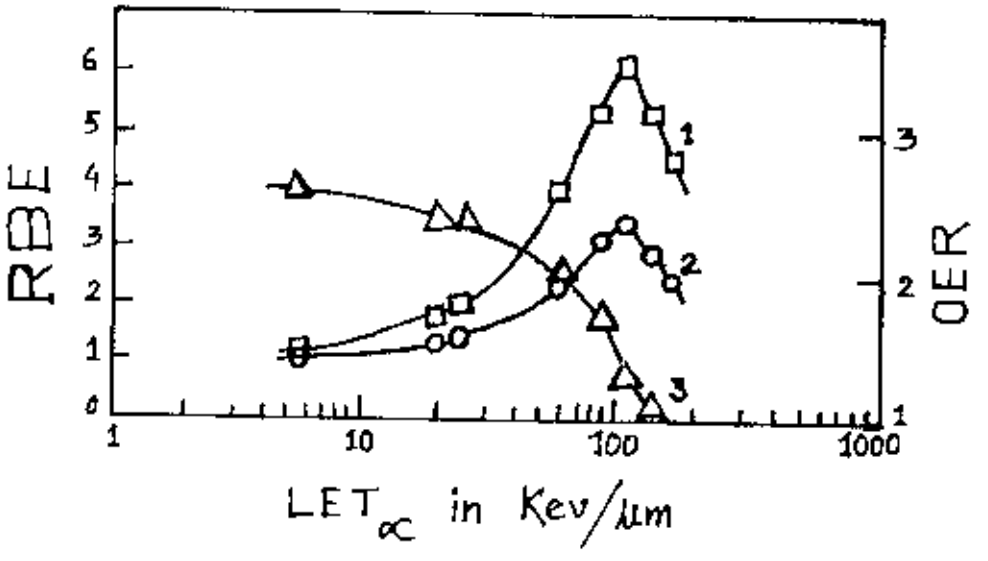


Fig 4.6[34] : Variation of RBE and OER plotted as a function of LET (dE/dx).

1. RBE for cell killing at higher survival level.
2. RBE for cell killing at lower survival level.
3. OER.

4.4 The Aim of Radiotherapy[35]:

There have been big advances in knowledge of radiobiology of tissues and their tolerance to fractionated radiotherapy since 1977. Basically, what we want to do is irradiate a cube of tissue containing the tumour.

We want:

1. No dose beyond the tumour, also no dose to the surface (skin).
2. No dose beyond the sides of the tumour.
3. Highest possible dose to the tumour.

But it is impossible to treat only tumour and not normal tissue.

2 ways to overcome this

1. Physical principles – blocking, collimation, shielding, tissue compensation, choice of appropriate energy.
2. Principles of fractionation – radiobiological principles.

4.4.1 Principles of Fractionation – The Four R's

1. Repair
2. Reoxygenation
3. Repopulation.
4. Reassortment

a. Repair of Cellular DNA

- Current belief = radiation exerts its effect by damaging DNA (not proven).
- We believe that between fractions, normal cells can repair their DNA whereas tumour cells do not have as great a capacity for this repair.
- It is postulated that the curve for acutely reacting normal tissues is shallower than that for tumours.
- Therefore, by giving smaller fractions, we allow the repair of normal tissues while still killing the tumour. Fractionation is thought to improve the therapeutic ratio
- Experimentally, repair of DNA in normal tissues is thought to take at least 6 hours. Important to leave 6 hours between fractions.

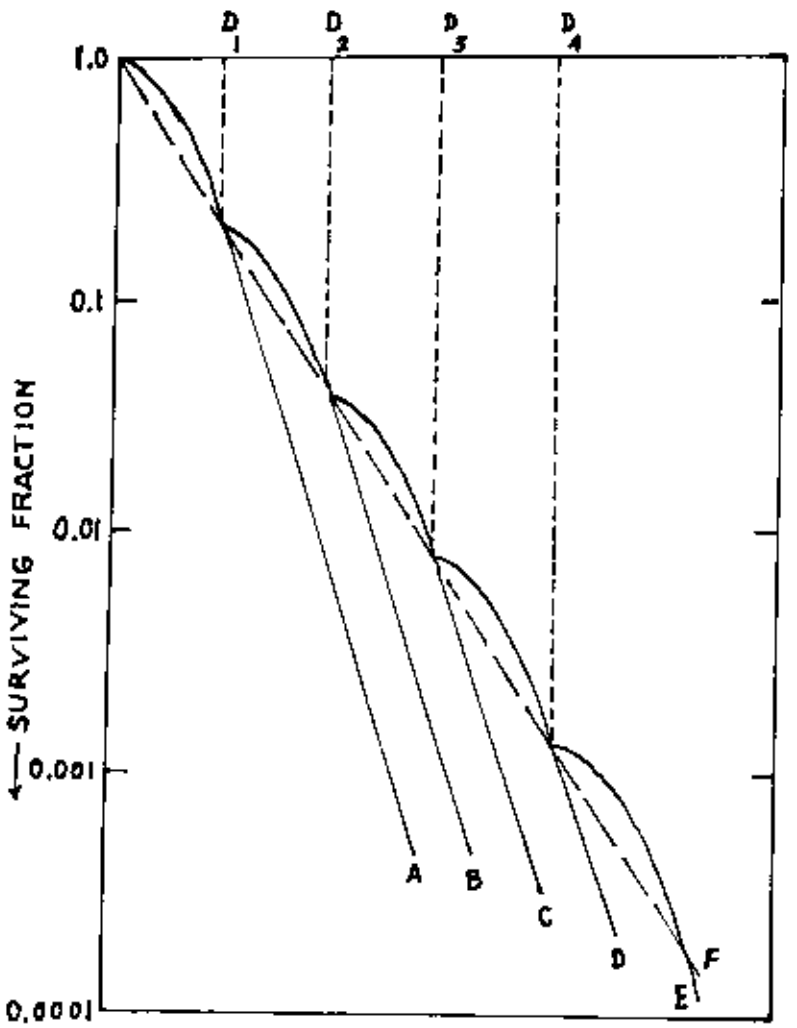


Fig 4.7[36] : Idealized fractionation experiment. Curve A is the survival curve for single acute exposures of X-rays. Curve F is obtained if each dose is given as a series of small fractions of size D_1 with an interval between fractions sufficient for repair of sublethal damage to take place. Multiple small fractions approximate to a continuous exposure to a low dose rate.

b. Reoxygenation:

- Radiotherapy works by ionizing atoms – as X- rays and electrons pass through water they knock electrons from atoms and cause the formation of free radicals.
- Free radicals attack the DNA in tumour and normal tissue cells.
- Most free radicals are deactivated – through combination with reducing agents – they are therefore short lived.
- However, if a free radical combines with Oxygen, it becomes longer lasting.
- Oxygen increases cell kill. Many tumours are hypoxic or have hypoxic parts to them whereas normal tissues are fully oxygenated.
- When parts of a tumour die, and a tumour become smaller, hypoxic parts of the tumour become oxygenated. If we leave time between fractions for oxygenation to occur, we can increase tumour kill.
- Because normal tissue cells are already fully oxygenated, fractionation does not change how many normal cells are killed.
- Experimentally, Reoxygenation of tumour cells takes in order of 6 hours.
- Experimentally, local control by radiotherapy correlates with haemoglobin levels.
- If a patient's Hb level is <10g/L, the local control of squamous cell Ca of the head and neck, cervix, bronchus and TCC bladder has been shown to be worse.

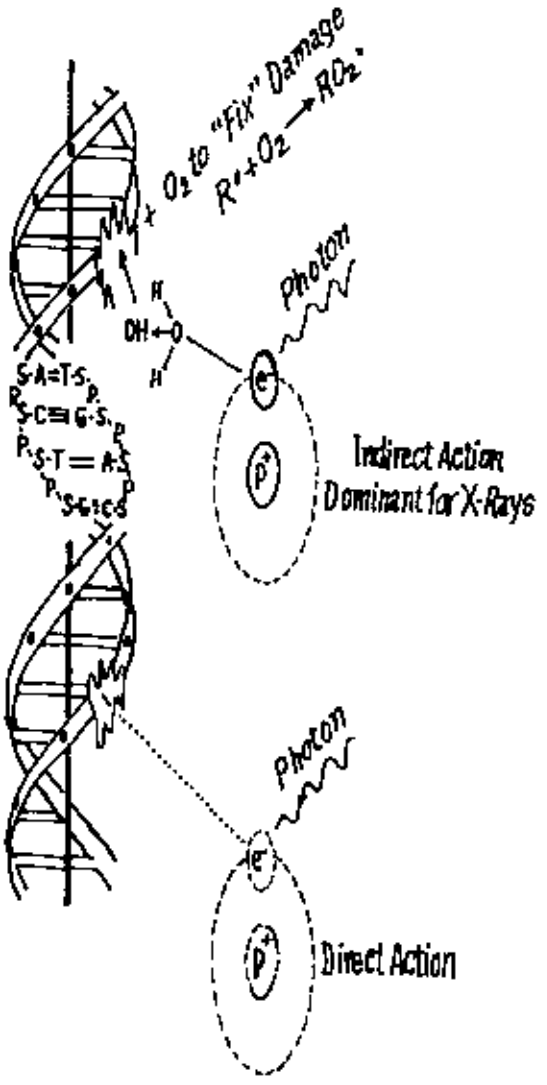


Fig 4.8[35]: The oxygen fixation hypothesis, about two thirds of the biological damage produced by X- rays is by indirect action, mediated by free radicals. The damage produced by free radicals in DNA can be repaired under hypoxia but may be "fixed" (made permanent and irreparable) if molecular oxygen is available

c. Repopulation :

- Many normal tissues increase their rate of repopulation due to insult by radiation (eg regeneration of skin). Tumours are thought not to be able to increase their rate of repopulation during a course of radiotherapy to the same degree.
- Accelerated Repopulation is a theory (Wither 1985) that if tumours are damaged but not killed by radiotherapy, they will grow at a faster rate than if they were never treated.
- Accelerated Repopulation experimentally seems to occur in fast growing tumours (head and neck, squamous cell carcinoma) after about 4 – 6 weeks of radiotherapy.
- Fractionation favors recovery of normal tissues over tumours due to repopulation.
- However, if a course of radiotherapy is delayed, the tumour will also repopulate. It is therefore theorized that prolonged treatment breaks are hazardous.

d. Reassortment:

The sensitivity of cell is dependent on many factors, one such factor is the^{0} position of the cell in its proliferation cycle.

- Certain phases – M and G_1 are more radiosensitive than others (late S). By fractionating the dose, we are able to catch more cells in the sensitive phase of the cell cycle – remember that tumour cells probably will cycle faster than the surrounding tissues.
- By fractionating the radiotherapy, we increase the chances of catching tumour cells when they are most sensitive to radiotherapy.

Fractionation increases tumour cell for a given amount of normal tissue damage. It increases kill to tumour cells by increasing reoxygenation of hypoxic cells and promoting reassortment of tumour cells into sensitive phases of the cell cycle. It spares normal tissue because it allows time in between fractions for them to repair and regenerate (they do this at a greater rate than tumours).

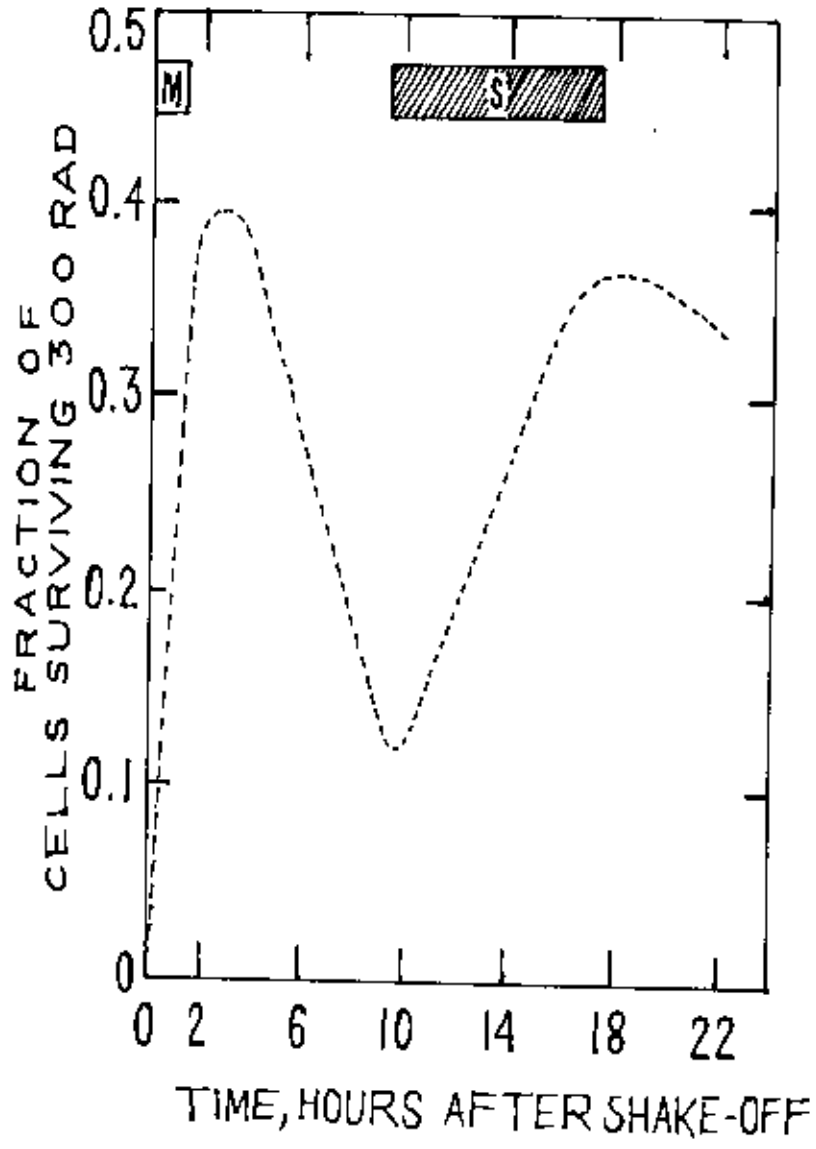


Fig 4.9[35]: Fraction of Hela cells showing a dose of 3 Gy of X rays administered at different times in the div. cycle. Time zero represents mitosis.

Chapter V

TREATMENT OF CERVICAL CANCER PATIENT WITH BRACHYTHERAPY

Treatment of Cervical Cancer Patient with Brachytherapy

5.1 Uterus

5.1.1 General Description[37]

The uterus is a thick walled, muscular, hollow organ shaped like a pear, its tapering end being the ***cervix*** which projects into the vagina. The measurements were formally given as 3x2x1in. It weighs 45-55g. The wall is 1-2 cm thick, so the length of the normal uterine cavity, including the cervical canal, is not less than 7 cm and is usually 7.5-8 cm.

The uterus is made up of a body or corpus, isthmus and cervix. The part of the body situated above the level of insertion of the fallopian tubes is described separately as the fundus, especially during pregnancy. The area of insertion of each fallopian tube is termed the cornu. The opening of the cervix into the vagina is the external os uteri.

The cavity of the uterus is triangular in shape when seen from the front, but is no more than a slit when seen from the side. It communicates with the vagina through the cervical canal, and with the lumen of each fallopian tube at the cornua.

5.1.2 The Relations of the Uterus

Anterior: The upper part of the uterus has the uterovesical pouch and either intestine or bladder in front of it. The lower part is closely associated with the base of the bladder from which it is separated only by loose connective tissue.

Posterior: Posteriorly lie the pouch of Doglas and the utero rectal pouch with coils of intestine. The vaginal cervix also has the posterior fornix behind it.

Lateral: Laterally is the broad ligament and its contents, especially the uterine artery which runs up the side of the uterus giving off branches at different levels. As it passes forward to reach the base of the bladder the ureter lies only 1 cm to the side of the supravaginal cervix – an extremely important point to the surgeon.

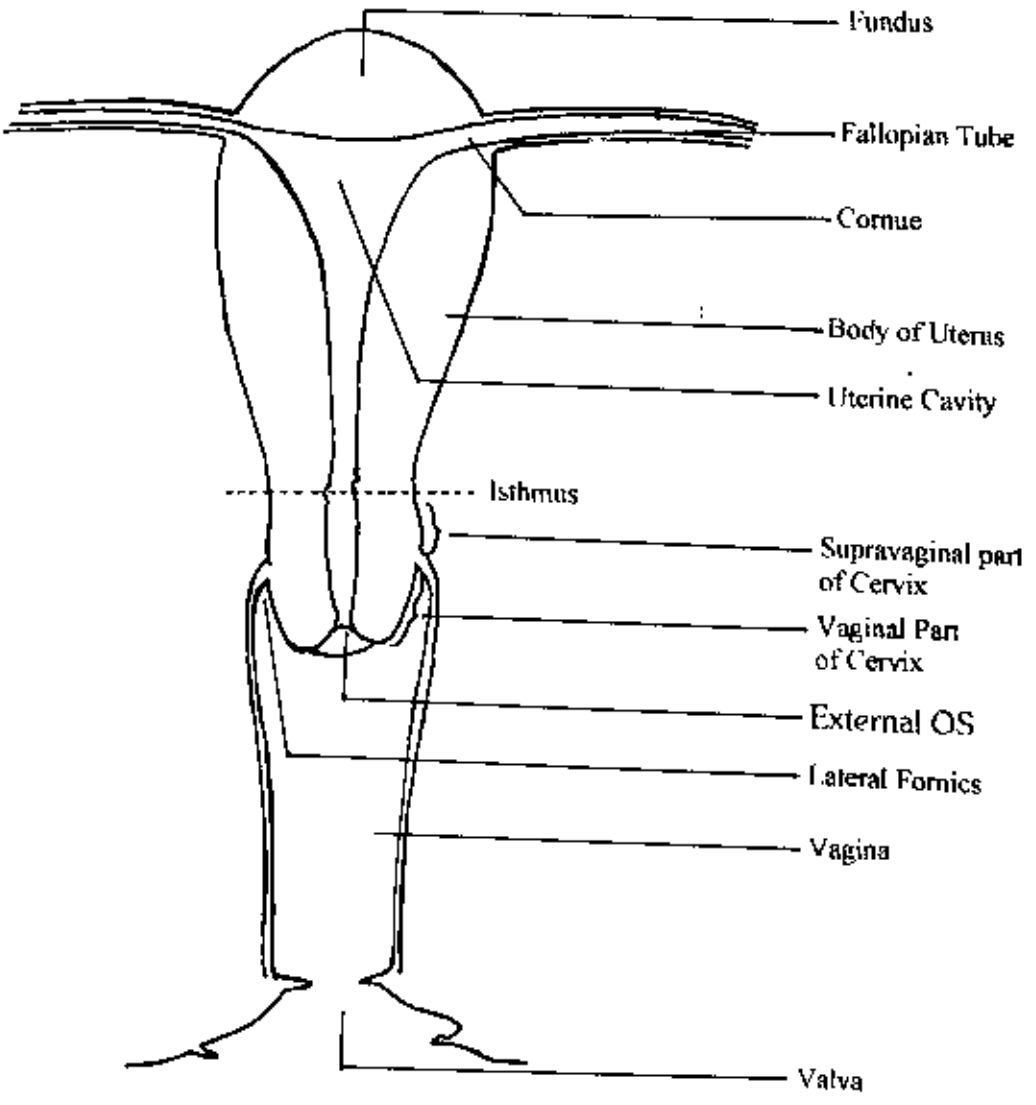


Fig 5.1[38]: Coronal plane of uterus, cervix and vagina.

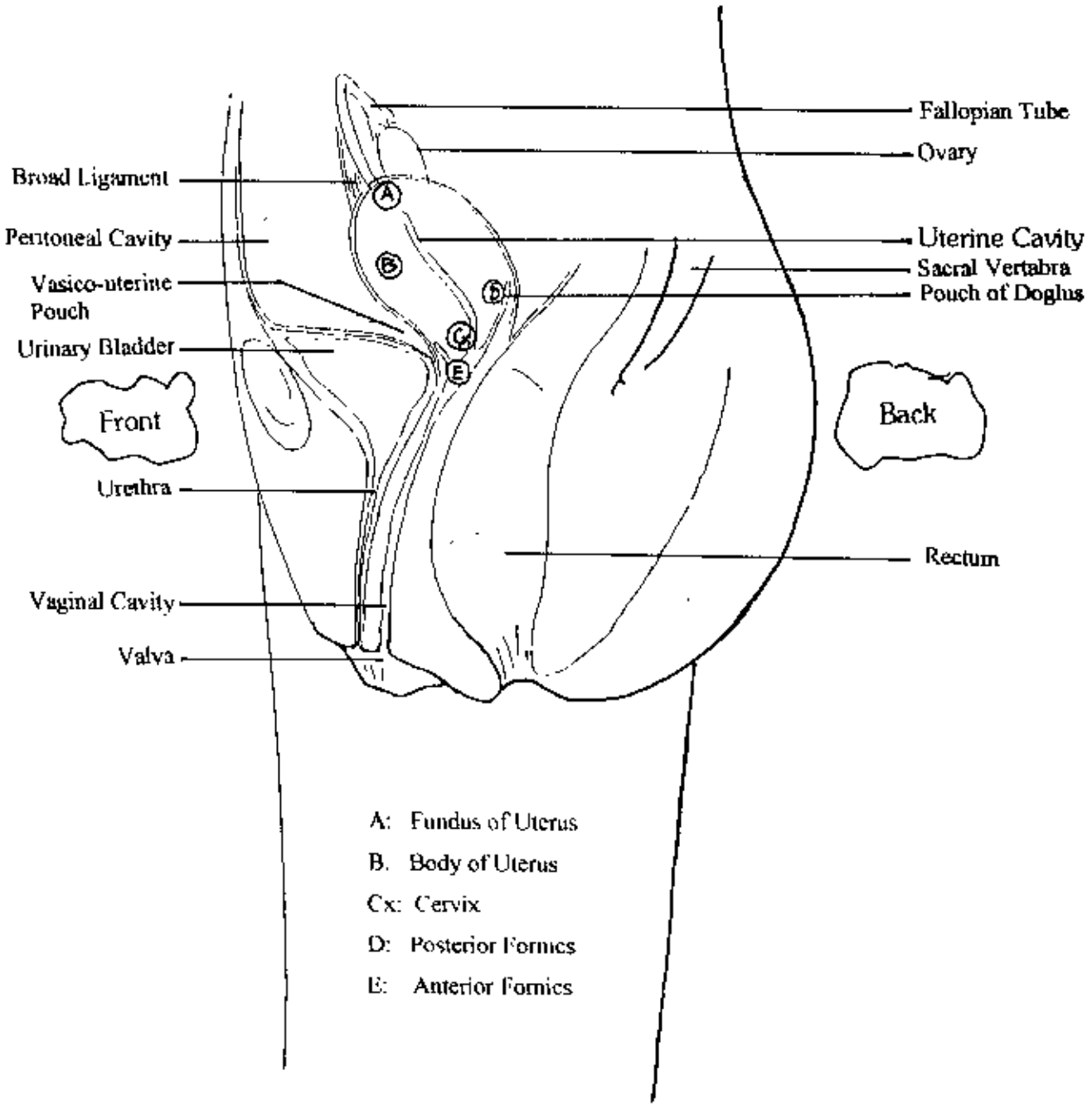


Fig 5.2[38]: Saggital plane of female pelvic organ .

5.2 Clinical Stages of Cervical Cancer [37]

In order to allow comparison of results of radiotherapy in various centers, the FIGO classification is shown in Fig 5.3 and below.

Stage I: Invasive growth confined to cervix.

(a) Preclinical invasion, including microinvasive carcinoma (early stromal invasion).

(b) Clinically diagnosed cancer, limited to the cervix or extending only to the corpus. Occult carcinoma is also included in this subgroup.

Stage II: Growth extending to.

(a) The vagina in its upper two-thirds, but not to the parametrium.

(b) The parametrium but not reaching the pelvic wall.

Stage III: Growth involving either

(a) The lower third of the vagina or,

(b) The parametrium as far as the pelvic wall .

all cases associated with hydronephrosis or non-functioning kidney.

Stage IV: Growth involving either

(a) The bladder or rectal mucosa, or

(b) Tissues outside the true pelvis .

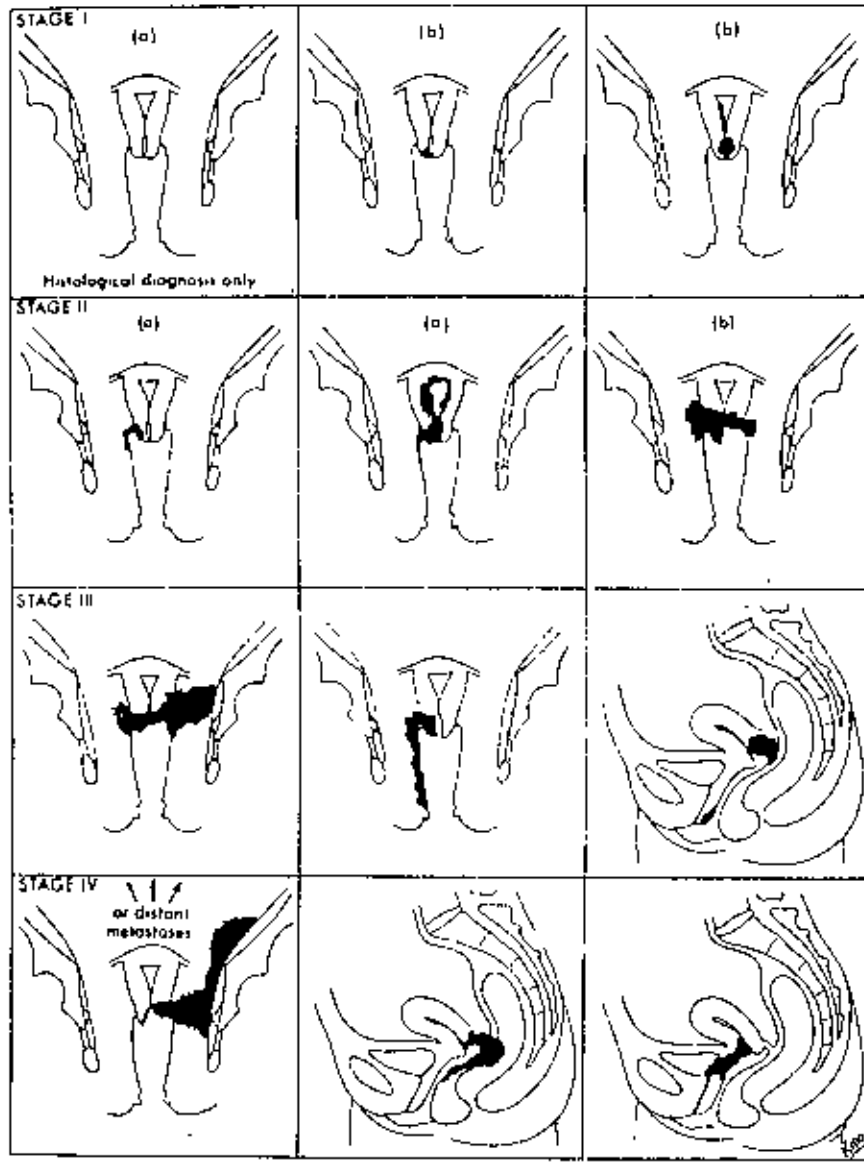


Fig 5.3[37]: The clinical staging of carcinoma of the cervix as agreed by the International Federation of Gynaecology and Obstetrics (FIGO).

5.3 Prognosis[37]

Irrespective of the type of treatment the prognosis depends on the following

- The extent and the growth at the time of treatment. This is the most important single factor.
- Site : An endocervical growth is potentially more dangerous than one which grows on the vaginal surface because it is diagnosed relatively late, and it spreads to the broad ligaments and to lymph nodes relatively early.
- Naked-eye appearance
- Histological type
- Age: The younger the patient the more likely is the growth to be poorly differentiated in type, and the worse the outlook.
- Ureteric obstruction.

5.4 Treatment of Cervical Cancer Patient[37]

Treatment is by radiotherapy, surgery or chemotherapy, or by combinations of these. It is now highly specialized, and the best results can only be obtained when there is good teamwork between gynaecologists, radiotherapists, physicists and others with a particular interest and experience.

Treatment with Radiotherapy:

This is the treatment of choice in the majority of cases and is applicable at all stages of disease. It aims at giving of cancericidal dose of gamma rays to all areas where there is growth or where there is likely to be growth. The tissues around the cervix (at point A) are exposed to 70-80 Gy, the outer part of the broad ligament to rather less. The first objective is generally achieved by Cs-137 intracavitary therapy, the second by Cobalt units or linear accelerator external beam therapy. In certain cases, especially advanced ones, the last is used to cover the whole field. When combinations are used, the dose of one agent is adjusted to that of the other to ensure that the total dose is not excessive. Despite all technical advances, however, intracavitary treatment centrally in the uterus and adjacent to the cervix in the vagina takes precedence over other forms of radiation. To reduce the dose of radiation to the adjacent bladder and rectum, vaginal packing is used to increase the distance between them and the source of radiation.

Gamma rays act by damaging the nuclear structures in actively dividing cells and by inducing a fibrous tissue and protective reaction in the host tissue. Radiosensitivity depends to a large extent on whether the tumour receives a good blood supply from its bed. This may mean that a high oxygen concentration is the determining factor. In favourable cases the tumour disappears within 6 weeks. Over dosage not only causes adverse reactions and permanent ill effects but is less likely to cure the carcinoma because it interferes with the host response. If the initial course of treatment offers a full cancericidal dose, radiotherapy can never be used again, even if the growth recurs.

According to ICRU 50 the treatment volume is shown in Fig-5.4 and Fig 5.5

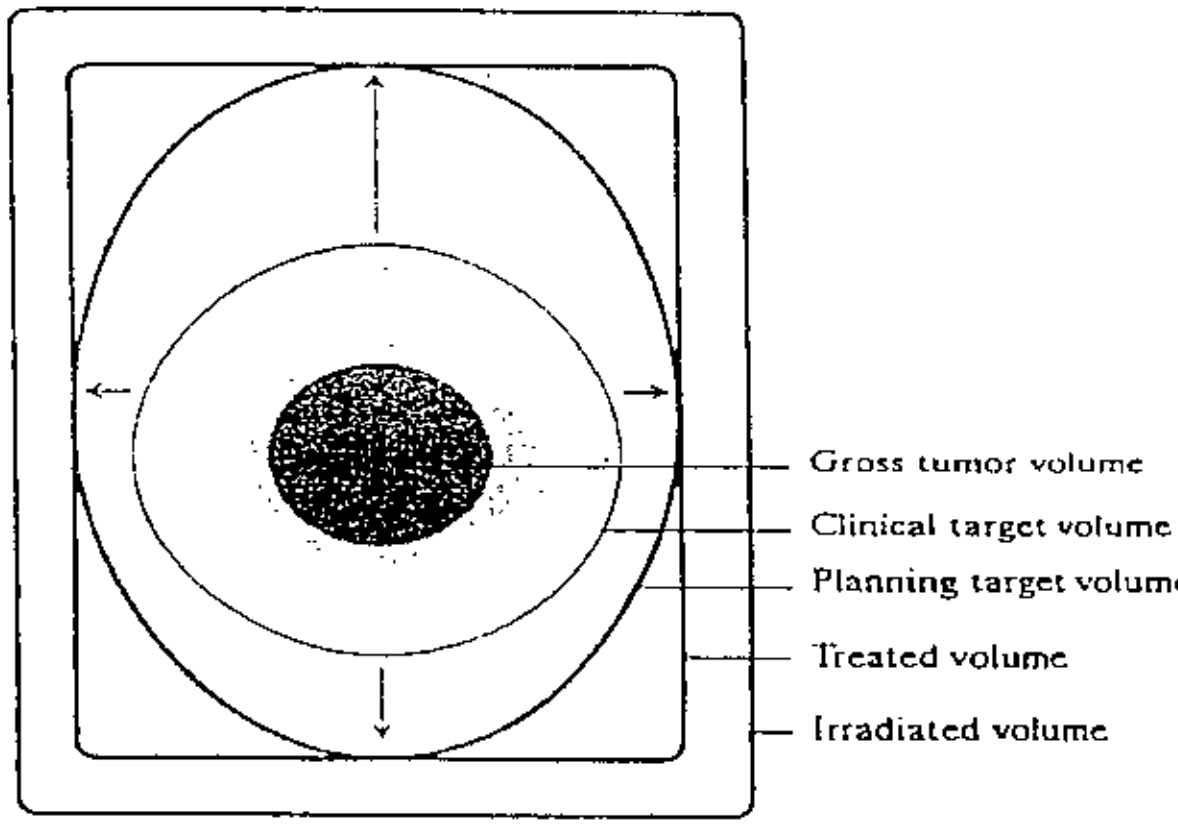


Fig 5.4[39]: Schematic illustration of the different volumes.

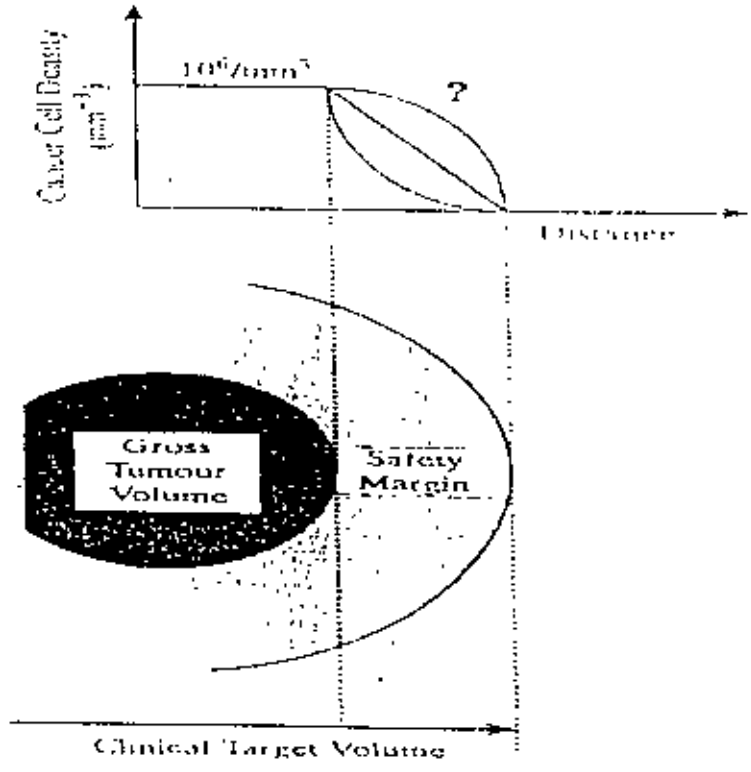


Fig 5.5[39]: Variation of malignant cell density in the gross tumour volume (GTV) and in the clinical target volume. In the gross tomour volume, the malignant cell density can be estimated to be $10^6/mm^3$ with of course large variations between tumours (histology, size, necrotic areas....). The malignant cell density decreases in the safety margin surrounding the GTV, and little information is available concerning the variation of the malignant cell density at that level.

5.5 Patient Preparation by Fletcher Suit Applicator[40]:

The physician will set the overall treatment policies for the brachytherapy programme and should participate in the design of the brachytherapy facility and the procurement of equipment. For individual patients, the physician is responsible for selecting and inserting the applicator or placing catheters, prescribing the dose, reviewing and approving the dose calculations, overseeing the dose delivery, removing the applicator or catheters, and the patients follow-up evaluation[40].

Steps Involving in Patient Preparation[41].

1. Immobilization of the patient on the patients couch.
2. Tumor localization.
3. Insertion of Fletcher suit applicator.
4. Placing folly catheter into the bladder, the balloon is filled with contrast dye.
5. Insertion of sterilized gauze into the vagina, which keeps the applicator at fixed position and minimize the radiation dose to a tolerance level at rectum and bladder. The rectum tolerance dose is 50-55 Gy and bladder tolerance dose is 70-75 Gy[42].
6. Placing a rectal marker, which is a plastic tube filled with Barium powder and this tube is covered by hand gloves.
7. Radiograph was taken by the simulator of the lower abdomen at AP and Lateral position.
8. After radiograph the rectal marker is removed .
9. The duty doctor inserted the source manually.

After patient preparation the source position is shown in (a).Fig-5.6 in coronal plane and (b).Fig 5.7 in Saggital plane.

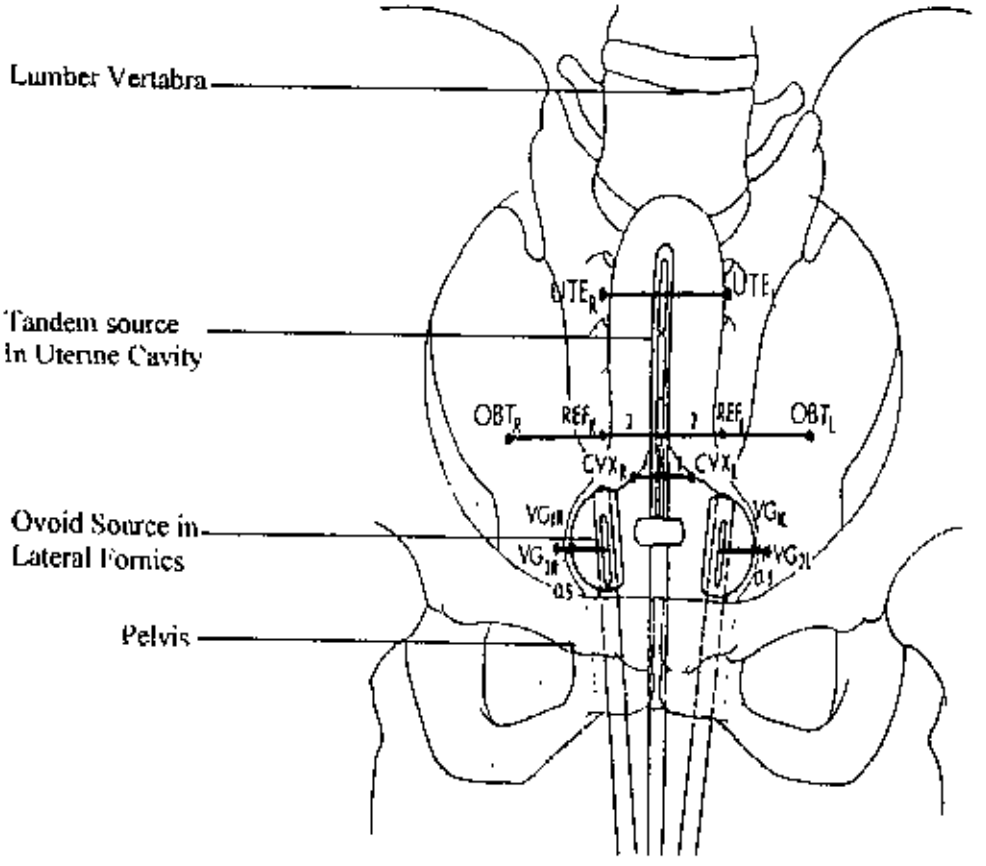


Fig 5.6[39]: Patient preparation with source at coronal plane

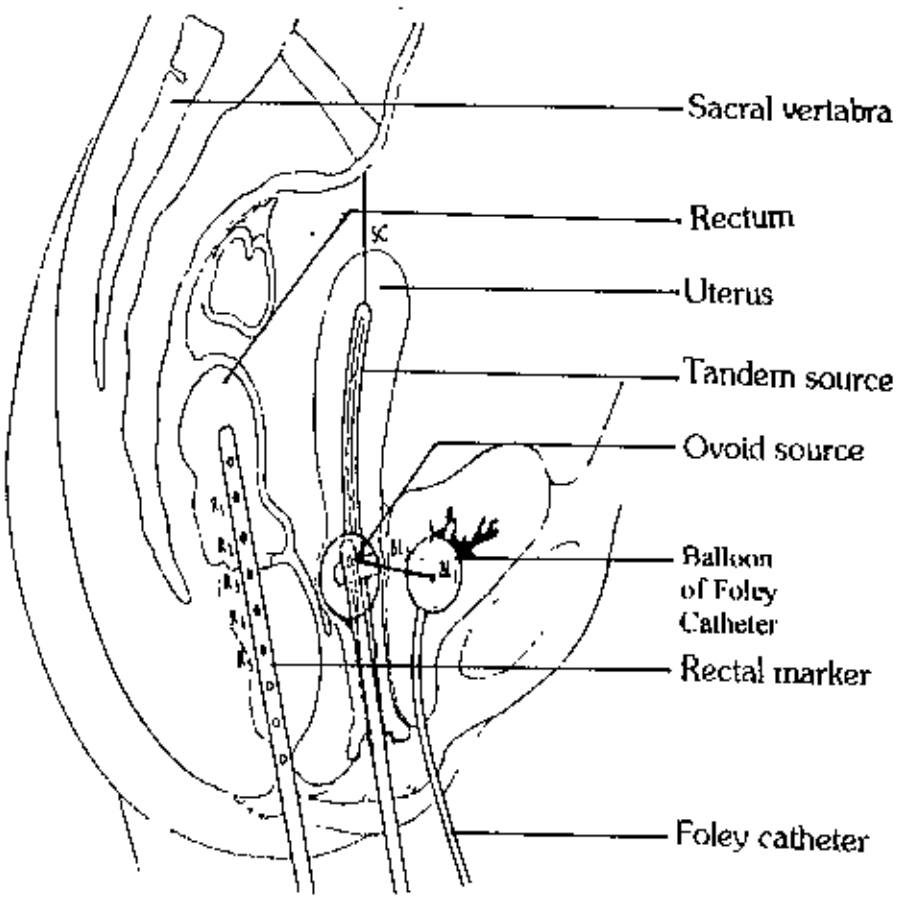


Fig 5.7[39]: Patient preparation with source at saggital plane

5.6 Responsibilities of the Radiation Oncologist and the Medical Physicist in Cancer Treatment[40]

5.6.1 The Radiation Oncologist (Physician, Medical Doctor)

The director of the radiation oncology department is responsible for the overall care of the patient.

Responsibilities:

- Consultation and clinical evaluation
- Establishment of treatment plan, including dose prescription
- Treatment execution, participation on a regular basis
- On-treatment evaluations and patient monitoring
- Treatment summary
- Follow-up and evaluation of the treatment

5.6.2 The Medical Physicist (Hospital Physicist, Radiation Oncology Physicist)

To provide a high standard of clinical physics service and supervision, responsibilities of medical physics covers the following areas:

- Specification of therapy equipment (external beam, brachytherapy, simulators, CT, and imaging systems, and treatment planning systems) assuring its radiation safety.
- Acceptance testing, commissioning and QA (including calibration) of therapy equipment
- Measurement and analysis of beam data; tabulation of beam data for clinical use
- Establishment of dose calculation procedures
- Establishment of treatment planning technical aspects and treatment procedures
- Evaluation and optimization of treatment planning
- Establishment of QA procedures in radiotherapy regarding delivery of the treatment, radiation safety, quality control and regulatory compliance
- Supervision of therapy equipment maintenance.

Chapter VI
METHODS AND MATERIAL

6.1 Methods

In radiation therapy the prescription is written before insertion of the source. In order to verify the correct delivery of irradiation, the target absorbed dose should be measured. In case of intracavitary brachytherapy patients, after patient preparation two simulator radiograph (AP and Lateral) is taken in every case. In this thesis work the absorbed dose at point "A" and "B" for tandem, near ovoid and distant ovoid was calculated from the AP X- ray radiograph and the rectum and bladder dose was calculated from the AP and Lateral X- ray radiograph. 18 patients were studied for this purpose. The treatment of all patients was performed in the oncological unit of Delta Medical Centre Ltd. Mirpur-1, Dhaka.

The theoretical algorithm for the calculation of dose distribution around a linear Cs-137 Low Dose Rate (LDR) brachytherapy source was performed by software developed in Fortran IV language, which worked on a PDP11/34 computer. The algorithm for the dose calculation is based on the following hypothesis[11].

1. The active elements are point like sources.
2. The self absorption of the source itself and the absorption in the steel wire which contains the source are negligible;
3. The attenuation of the steel capsule, which contains the radioactive element, and the attenuation of the alternated inactive steel spheres are evaluated for each position.

With these assumptions, the dose around the source was obtained by the expression:

$$\underset{w}{\text{Dose}}\,(\Delta m, P) = \Gamma * f * \sum_{i=1}^{N} \frac{A(i)}{r_i^2} * \exp\left(-\mu_s\, ds_i\right) * g(dt_i)$$

.....(1)

where, $\Gamma = 3.32(R*h^{-1}*mCi^{-1}*cm^2)$

Is the gamma specific constant for the Cs-137 source.

f = 0.966 is the Rad /Roentgen factor.

A (i) is the activity of the "i" point source;

r_i is the distance of the "i" point source from point "p";

μ_s =0 47 per cm, is the linear attenuation coefficient of steel for 661.6 KeV gamma ray ;

ds_i is the sum of the radiation paths in the steel capsule and in the alternated spheres;

$dt_i = r_i - ds_i$ is the actual path in the tissue;

here;

For near ovoid and tandem,the value of $ds_i^{(43)}$ = 0.6mm(filtration) +1mm (flexible tube wall) +0.5mm (steel wall)

= 0.21cm.

$dt_i = r_i - 0.21$

For distant ovoid, $ds_i^{(43)}$ = 0.6mm(filtration) +1mm(flexible tube wall) +0.5mm (steel wall) +0.5mm (steel wall of cenral applicator) +2mm (two walls of flexible tube of central applicator) +0.5mm (steel wall of central applicator)

= 0.51cm.

$dt_i = r_i - 0.51$

$g(dt_i) = A + B\,dt_i + C\,dt_i^2 + D\,dt_i^3$ is the polynomial of Meisberger[3],

with $A = 1.0091*10^0$, $B = -9.015*10^{-3}$, $C = -3.459*10^{-4}$,

$D = -2.817*10^{-5}$

These coefficients are the results of an optimization. This polynomial is commonly used for routine calculation of absorbed dose in tissue in various computer programming[44].

6.2 Materials

The clinical material included 18 patients with carcinoma of the uterine cervix of different clinical stages of the disease. The material consisted of 13 patients with stage IIb and 5 patients with stage III b.

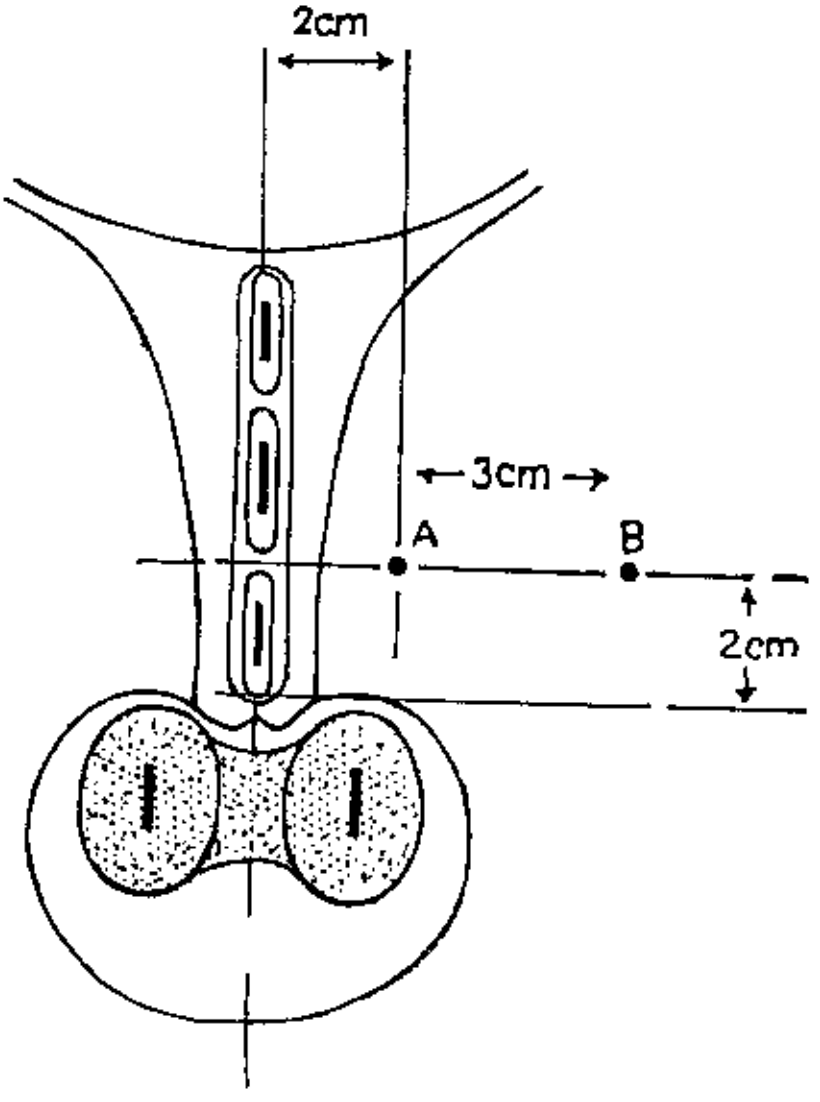


Fig 6.1[45]: Ideal geometry of points A and B.

6.3 The Method of Calculation of Patient's Absorbed Dose is Discussed Bellow.

Patient no 16:

Name: Mrs. Monowara.

Age: 45yr's.

Reg no: 00/1082

Diagnosis: CA cervix Stage IIJ b

Intracavitary Applicator:

Uterine tube length – 5cm

Ovoid – 2cm

Prescribed dose at 'A' = 2578 cGy

Total radioactivity:

360 mci = 13.32 GBq

Dose rate (cGy/ hr) = 127.82

Total no of sources: 5+(2+2)

Total treatment time = 20.16

Where, each source activity = 40mCi

So, for 9 sources the total activity = 40 * 9 mCi = 360 mCi

Including decay correction factor for each source, the activity, A = 40 *0.9082 mCi

Putting the value of Γ, f, μ_s, A in equation-1

For near ovoid and tandem the dose rate = 105.56 $g(dt_i) /r_i^2$)

For distant ovoid the dose rate = 91.676 $g(dt_i) /r_i^2$)

Magnification factor,

1. For AP radiograph μ =1.19
2. For lateral radiograph μ =1.37

Actual distance = Measured distance / μ

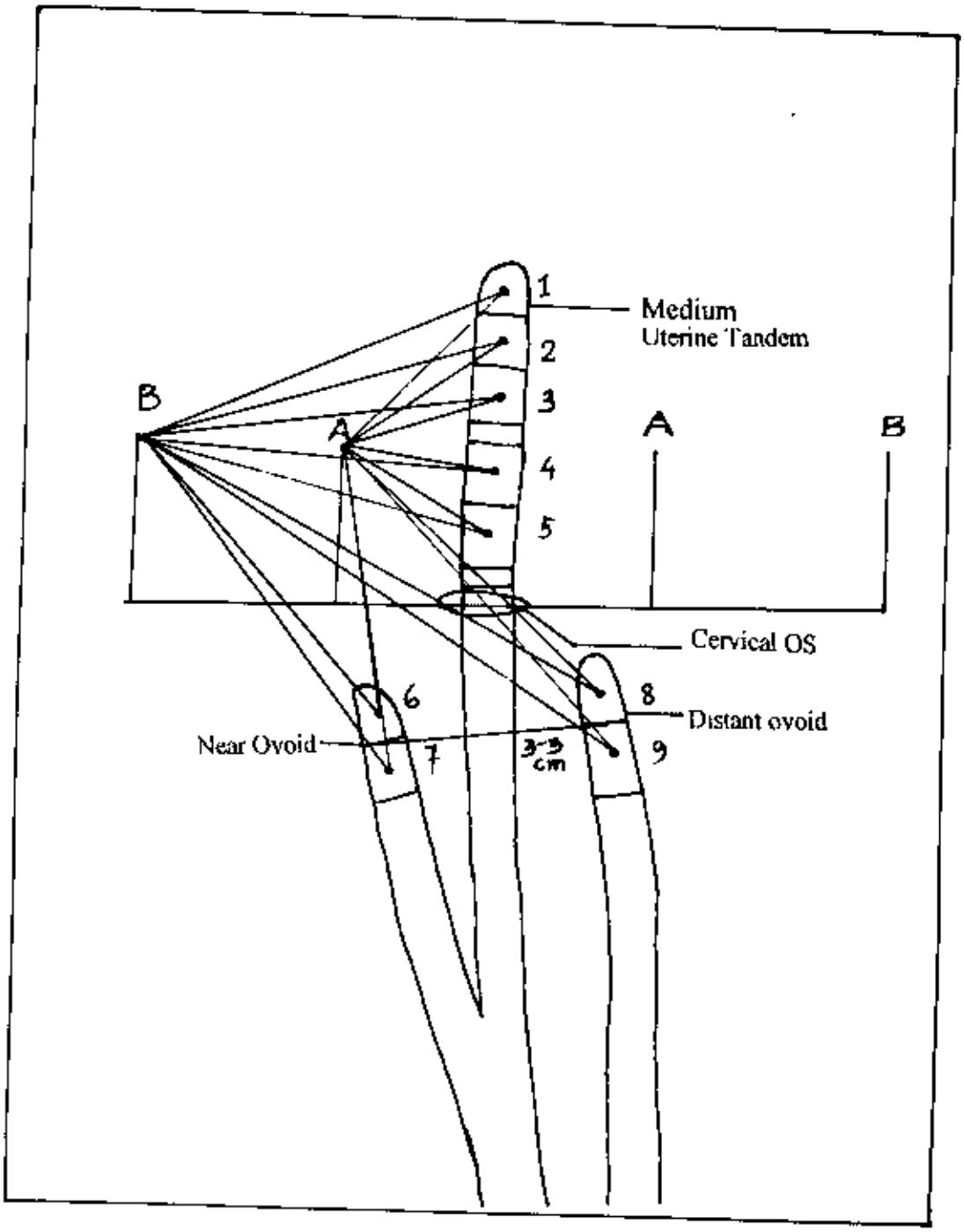


Fig 6.2: AP X- ray radiograph of cervical cancer patient.

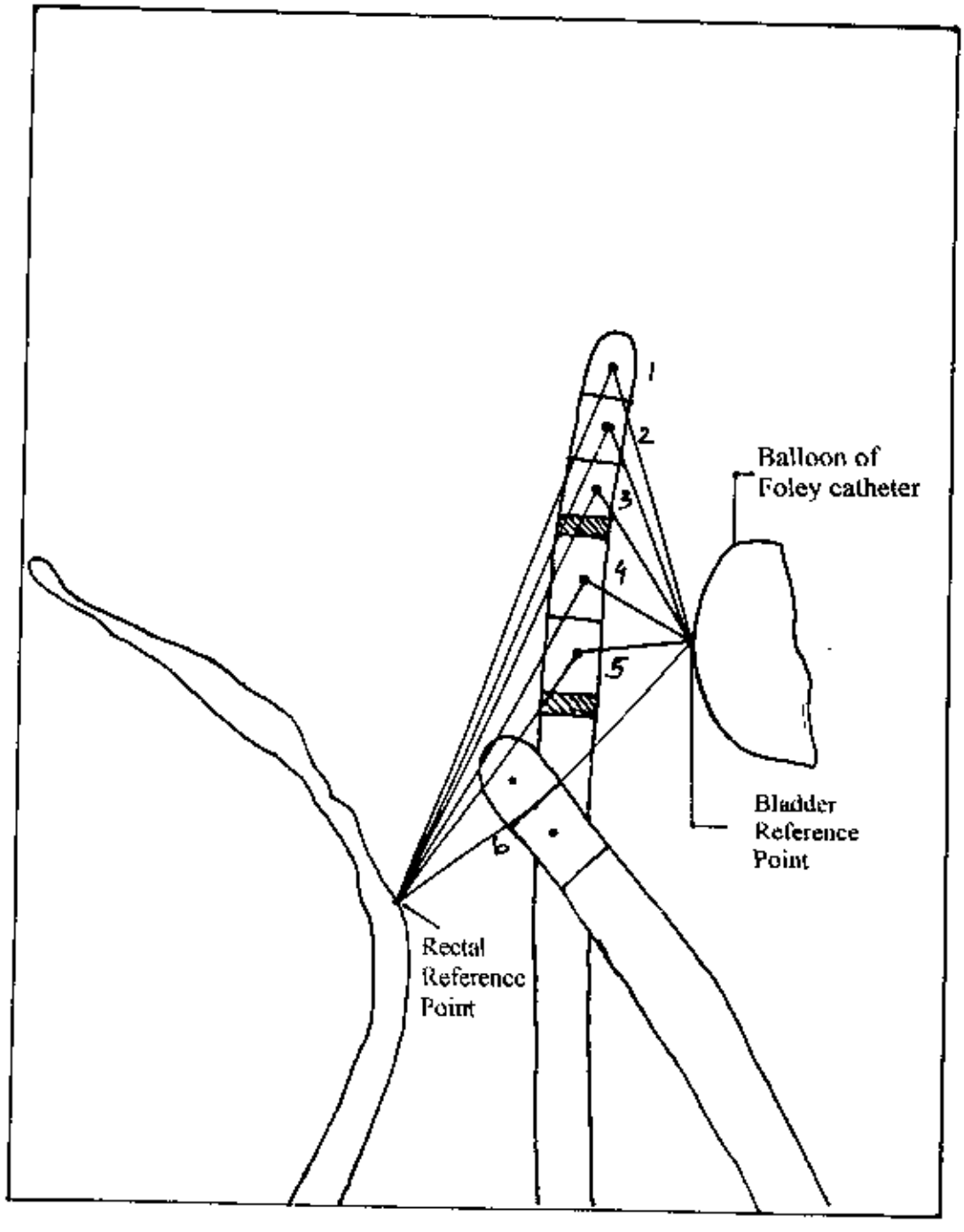


Fig 6.3: Lateral X-ray radiograph of cervical cancer patient

Table 6.1: Calculation of A point dose (Treatment time = 20.16 hr)

Source position no	Measured distance (cm)	Actual distance, r_i (cm)	$1/r_i^2$	$g(dt_i)$	Dose rate at this distance (cGy/ hr)
1	3.4	2.857	0.1225	0.982	12.67
2	2.9	2.437	0.1684	0.987	17.54
3	2.5	2.10	0.2265	0.990	23.69
4	2.4	2.02	0.246	0.992	25.73
5	2.7	2.269	0 194	0.989	20.25
6	4	3.36	0.0885	0.976	9.12
7	5	4.2	0.0566	0.966	5.77
8	5.4	4.54	0 0486	0.965	4.30
9	6.2	5.21	0.0368	0.956	3.23
Total dose rate	-	-	-	-	122.3
Total absorbed dose(cGy)	-	-	-	-	2465.6

Table 6.2: Calculation of B point dose (Treatment time = 20.16 hr)

Source position no	Measured distance (cm)	Actual distance, r_i (cm)	$1/r_i^2$	$g(d_i)$	Dose rate at this distance (cGy/ hr)
1	6	5.04	0.039	0.954	3.96
2	5.7	4.79	0.044	0.958	4.40
3	5.5	4.62	0.047	0.960	4.74
4	5.4	4.54	0.048	0.961	4.93
5	5.5	4.62	0.047	0.960	4.74
6	5.4	4.54	0.048	0.961	4.93
7	6.2	5.21	0 037	0.952	3.70
8	7.9	6.64	0.023	0.934	1.94
9	8.5	7.14	0.019	0.926	1.66
Total dose rate	-	-	-	-	35
Total absorbed dose(cGy)	-	-	-	-	705.6

6.4 Absorbed Dose at ICRU Reference Points[4]

Bladder Reference Point:

The bladder point is localized by using a Foley catheter, with the balloon filled with a contrast material. On the frontal radiograph, the bladder point is marked at the center of the balloon; on the lateral radiograph, the bladder point is obtained on a line drawn anteroposteriorly through the center of the balloon, at the posterior surface (Fig-6.4).

Rectal Point:

The rectal point is identified on the frontal radiograph at the midpoint of the ovoid sources (or the lower end of the intrauterine source). On the lateral radiograph, the rectal point is located on a line drawn from the middle of the ovoid sources, 5 mm behind the posterior vaginal wall (Fig-6.2). The posterior vaginal wall may be visualized by using radio opaque gauze for the vaginal packing.

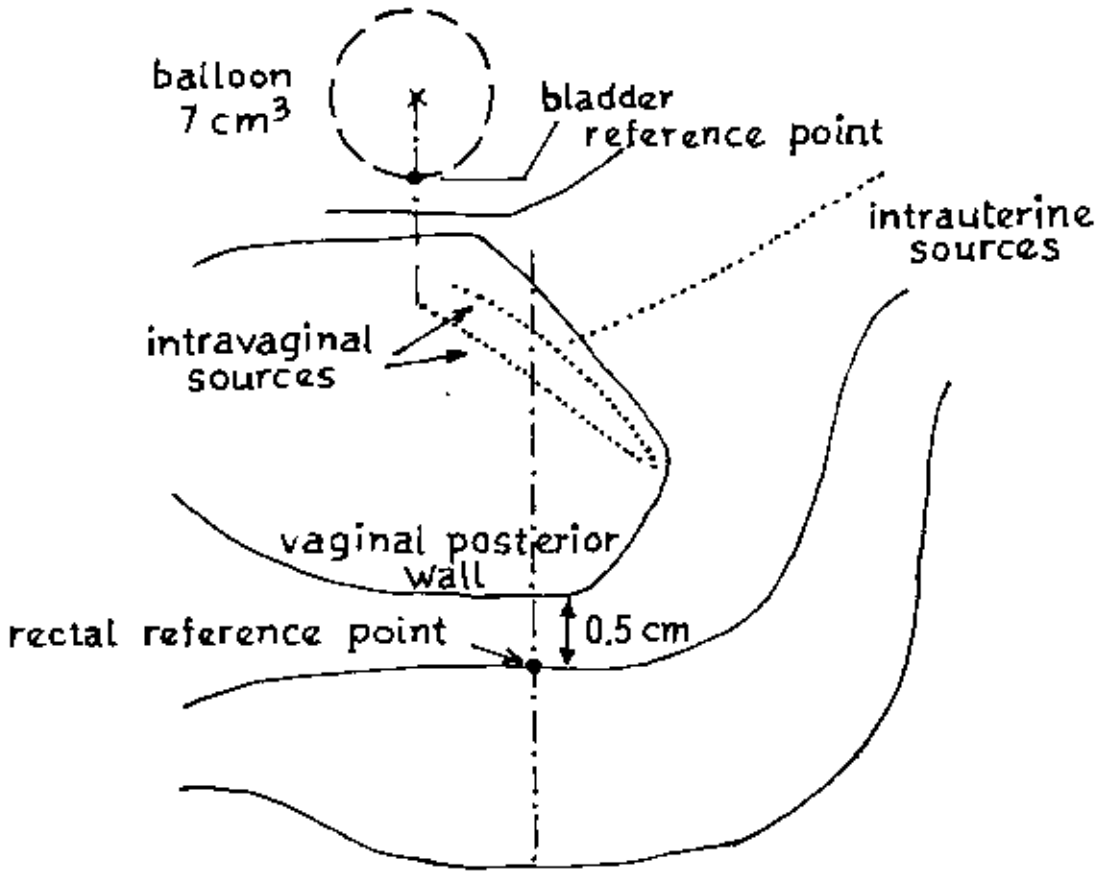


Fig 6.4[46]: Localization of bladder and rectum reference points

6.5 Calculation of Bladder Absorbed Dose

The measured distance between the mid point of two ovoid sources and bladder reference point = 3.4 cm, this is found from the X - ray lateral view.

The actual distance AB = 3.4/1.37 = 2.482 cm.

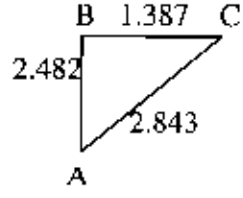
The measured distance between two vaginal ovoid sources = 3.3 cm, this is found from the X- ray AP view.

The actual distance CC = 3.3/1.19 = 2.77 cm, BC = CC/2 = 1.387 cm

So the distance from the bladder reference point to the source

AC $= (1.387^2 + 2.482^2)^{1/2} = 2.843$ cm

Each ovoid contains two sources of 40 mCi.



C = Ovoid Source = 40 mCi

A = Bladder reference point

Table 6.3: Calculation of bladder reference point dose (Treatment time = 20.16 hr)

Source position no	Measured distance (cm)	Actual distance, r_i (cm)	$1/r_i^2$	$g(dt_i)$	Dose rate at this distance (cGy/ hr)
1	4.3	3 14	0.10	0.979	10.33
2	3.5	2.55	0.15	0.986	15.95
3	2.7	1.97	0.26	0.992	26.91
4	1.9	1.39	0.52	0.998	54.78
5	1.8	1.31	0.58	0.999	61.16
6	-	2.84	0.123	0.982	51.10(for 4 ovoid sources)
Total dose rate	-	-	-	-	220.22
Total absorbed dose(cGy)	-	-	-	-	4439

6.6 Calculation of Rectum absorbed dose

The measured distance between the mid point of two ovoid sources and rectum reference point = 2.7 cm, this is found from the X - ray lateral view.

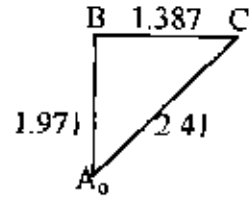
The actual distance $A_oB = 2.7/1.37 = 1.971$ cm.

The measured distance between two vaginal ovoid sources = 3.3 cm, this is found from the X- ray AP view.

The actual distance CC = 3.3/1.19 = 2.77 cm, CC/2 = 1.387 cm

So the distance from the bladder reference point to the source

$A_oC = (.387^2 + 1.971^2)^{1/2} = 2.41$ cm, each ovoid contains two sources of 40 mCi.



C = Ovoid source = 40 mCi

A_o = Rectum reference point

Table 6.4: Calculation of Rectum reference point dose (Treatment time = 20.16 hr)

Source position no	Measured distance (cm)	Actual distance, r_i (cm)	$1/r_i^2$	$g(dt_i)$	Dose rate at this distance (cGy/ hr)
1	8.8	6.423	0.024	0.933	2.38
2	7.8	5.693	0.031	0.945	3.08
3	6.9	5.037	0.039	0.960	3.99
4	5.7	4.160	0.058	0.966	5.89
5	4.7	3.430	0.085	0.976	8.75
6	-	2.410	0.172	0.987	71.78(for 4 ovoid sources)
Total dose rate	-	-	-	-	95.86
Total absorbed dose(cGy)	-	-	-	-	1932

Chapter VII

RESULTS AND DISCUSSION

Results

Case –1

Date: 07.10.03

Name: Mrs. Halima Begum

Prescribed dose at 'A' = 2700 cGy

Age: 64, Reg no: 03/1211

Total radioactivity: 440 × 0.84 (=372.76 mCi) = 13.79 GBq

Diagnosis: CA cervix Stage III b

Dose rate (cGy/ hr) = 131.48

Intracavitary Applicator:

Total no of sources:

Uterine tube length – 6 cm

Uterine source – 7+(2+2)

Ovoid – Small

Total treatment time = 20.53 hr

Table 7.1: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-1.

Applicator	Source position no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B. (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Long Uterine Tandem	1.	5.09	2.396	2.884	0.961
	2.	6.95	2.7	3.633	1.118
	3.	9.44	3.075	4.58	1.35
	4.	15.53	3.5	7.22	1.787
	5.	22.78	3.637	10.00	2.214
	6.	27.116	3.763	15.45	3.113
	7.	20.99	3.637	18.88	4.108
Near ovoid	8.	11.93	4.53	6.6529	11.765
	9.	7.65	3.637	6.6529	11.765
Distant ovoid	10.	4.086	1.537	6.6529	11.765
	11.	3.365	1.432	6.6529	11.765
Total dose rate	–	134.927	33.84	89.26	61.711
Total dose (cGy)	–	2770	694.8	1832.5	1267

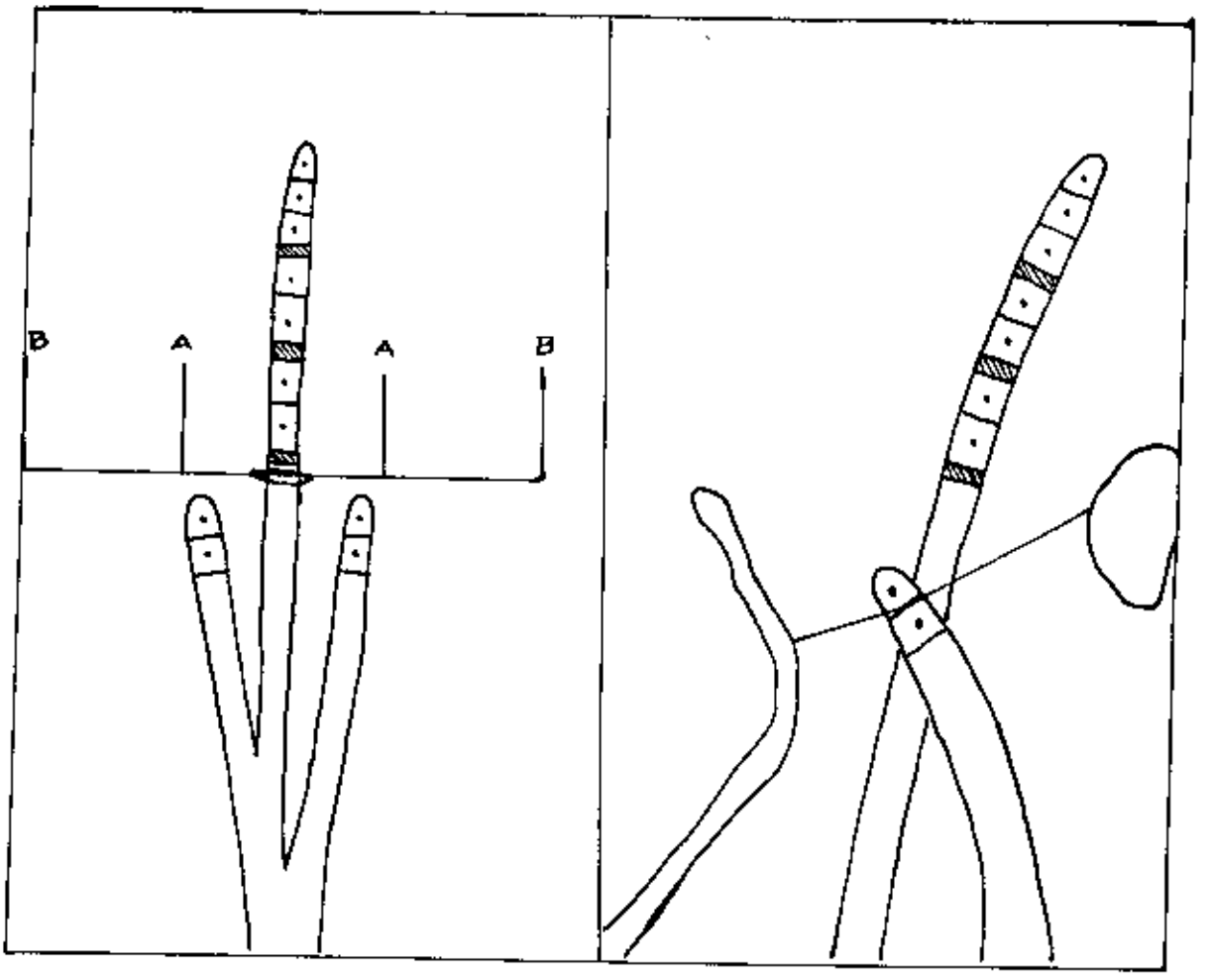


Fig 7.1: (a) AP and (b) Lateral X-ray radiograph of patient no-1

Case -2:

Date: 19.03.02

Name: Mrs. Razia Akhter

Prescribed dose at 'A' = 2600 cGy

Age: 52

Total radioactivity:

Reg no: 02/354

360 mCi = 13.32 GBq

Diagnosis: CA cervix Stage IIb

Dose rate (cGy/ hr) = 123.54

Intracavitary Applicator: Uterine tube

Total no of sources: = 5 + (2 + 2).

length – 5 cm

Total treatment time = 21.05 hr

Ovoid – 2cm

Table 7.2: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-2.

Applicator	Source position no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B. (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Medium Uterine Tandem	1.	19.58	3.7	17.03	2.04
	2.	24.785	3.88	27.13	2.458
	3.	22.847	3.88	40.798	3.202
	4.	15.911	3.457	44.833	4.84
	5.	13.81	3.15	27.13	6.65
Near ovoid	6.	10.199	4.42	6.697	15.133
	7.	6.6296	3.366	6.697	15.133
Distant ovoid	8.	4.605	1 682	6.697	15.133
	9.	3.542	1.532	6.697	15.133
Total dose rate	_	121.9085	29 06	183.716	79.728
Total dose (cGy)	_	2566.174	611.7	3867.23	1678

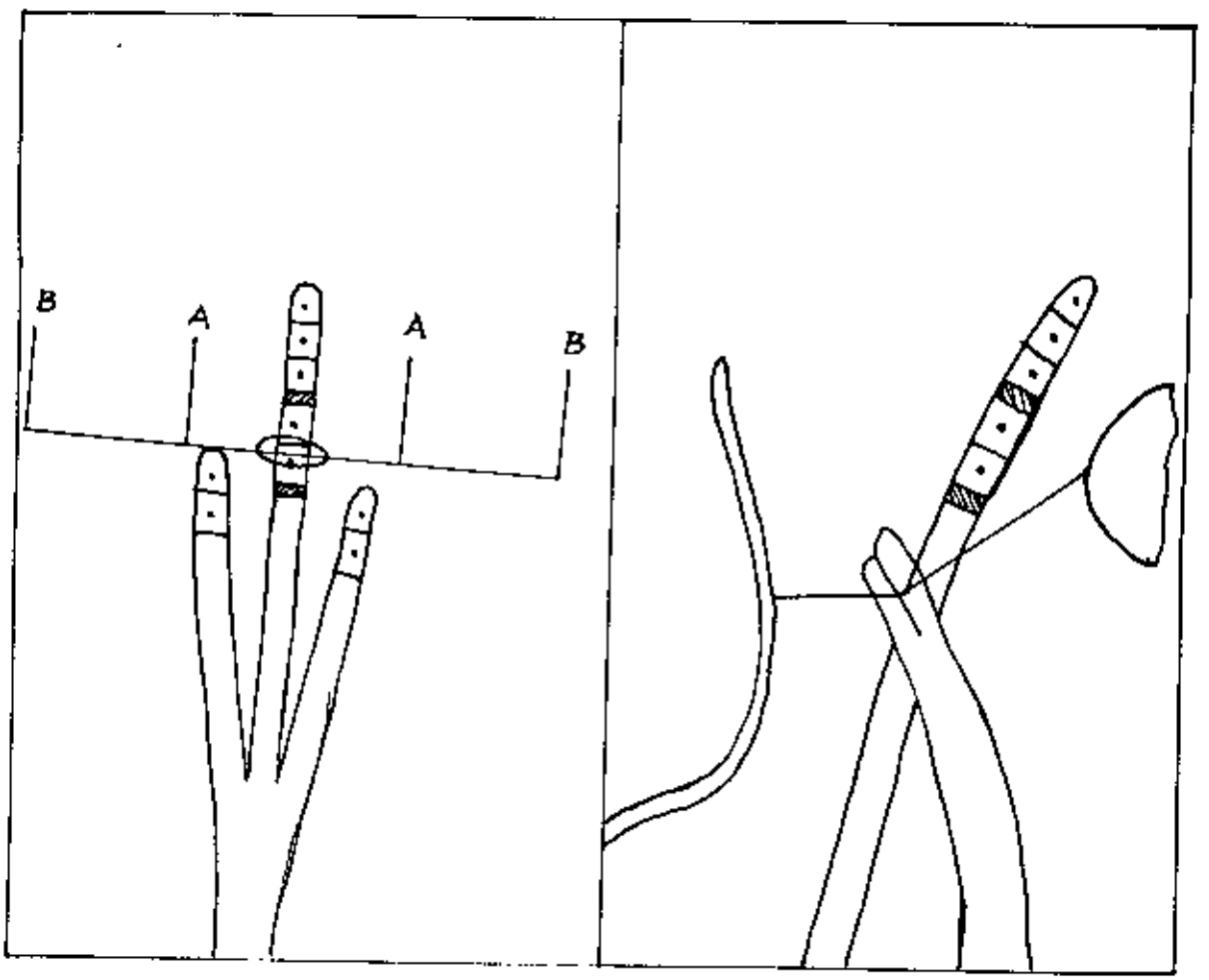


Fig 7.2: (a) AP and (b) Lateral X-ray radiograph of patient no-2

Case -3:

Date: 21.01.02

Name: Mrs. Laila Begum

Age: 46,

Reg no: 02/38

Diagnosis: CA cervix Stage II b

Intracavitary Applicator: Uterine tube

length – 6 cm

Ovoid – 2.5cm

Prescribed dose at 'A' = 3000 cGy

Total radioactivity:

440 mCi = 16.28 GBq

Dose rate (cGy/ hr) = 136.67

Total no of sources: 7 +(2 +2).

Total treatment time = 21 95 hr

Table 7.3: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-3.

Applicator	Source position no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B. (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Long Uterine Tandem	1.	7.15	2.97	2.29	1.055
	2	9.63	3.27	2.795	1.229
	3.	13.49	3.7126	3 52	1.433
	4.	21.95	3.955	5.354	1.843
	5.	25.76	4.117	7.64	2.283
	6.	17.47	3.955	13.72	2.97
	7.	12.69	3.603	22.83	3.378
Near ovoid	8.	12	4.43	6.301	11.688
	9.	7.51	3.724	6.301	11.688
Distant ovoid	10.	4.445	1.76	6.301	11.688
	11.	3.845	1.67	6.301	11.688
Total dose rate	_	135.939	36.277	83.353	60.94
Total dose (cGy)	_	2983.85	815.78	1830	1337.7

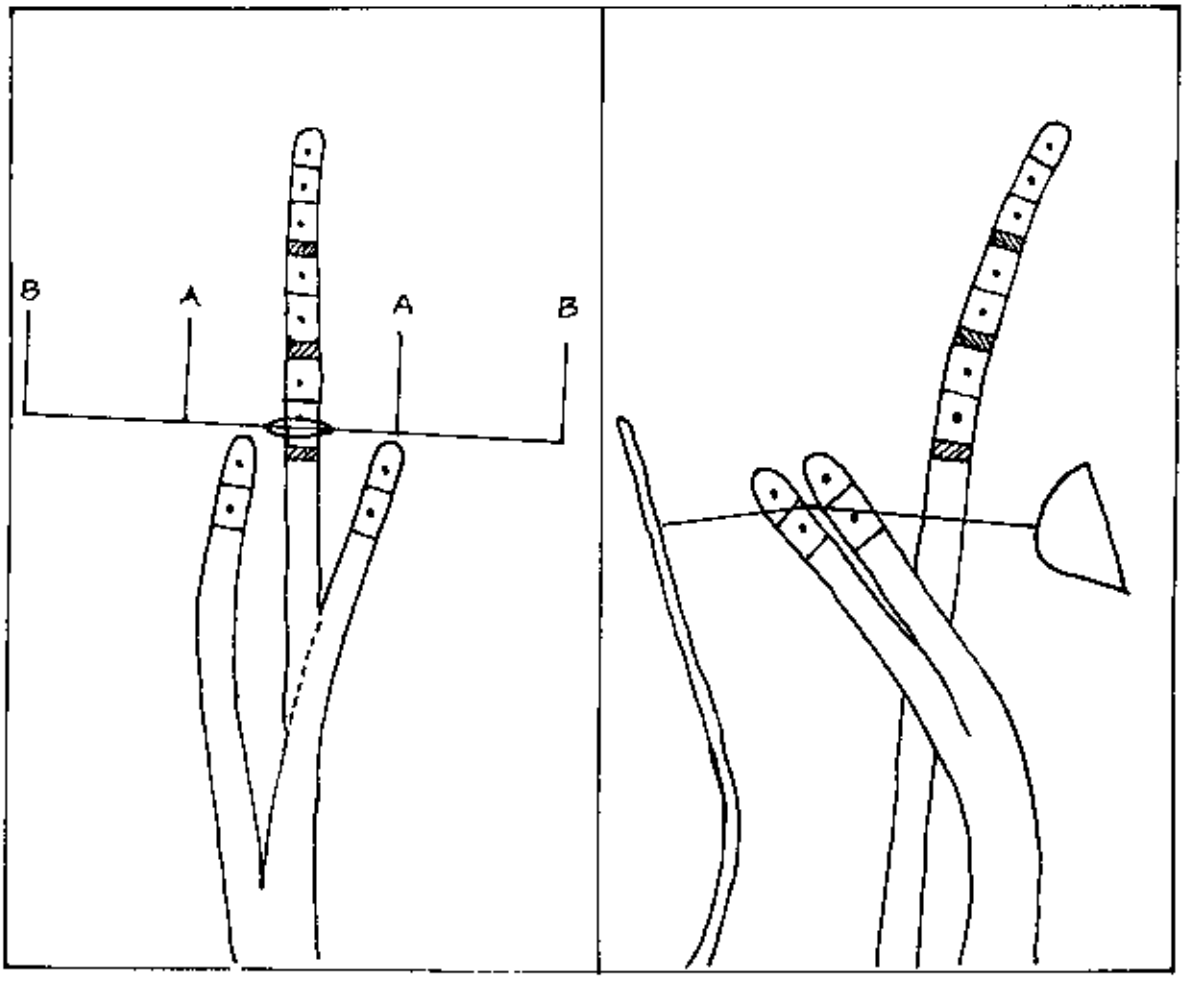


Fig 7.3: (a) AP and (b) Lateral X-ray radiograph of patient no-3

Case -4:

Date: 19.01.02

Name: Mrs. Sufia.

Age: 40

Reg no: 1461/01

Diagnosis: CA cervix Stage II b

Intracavitary Applicator: Uterine tube length – 4cm

Ovoid – 2cm

Prescribed dose at 'A' = 2500 cGy

Total radioactivity:

360 mCi = 13.32 GBq

Dose rate (cGy/ hr) = 124.56

Total no of sources: 5 +(2 +2).

Total treatment time = 20.06 hr

Table 7.4: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-4.

Applicator	Source position no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B. (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Medium Uterine Tandem	1	19.045	3.727	8.55	1.781
	2.	24.061	3.911	12.8	2.14
	3.	24.061	3.911	22.53	2.60
	4.	16.28	3.464	48.84	3.686
	5.	11.16	3.25	78.43	4.77
Near ovoid	6.	15.256	4.812	9.522	8.411
	7.	9.481	4.124	9.522	8.411
Distant ovoid	8.	3.378	1.39	9.522	8.411
	9	3.04	1.335	9.522	8.411
Total dose rate	_	125.762	29.924	209.23	48 623
Total dose (cGy)	_	2522.8	600.3	4197	975.4

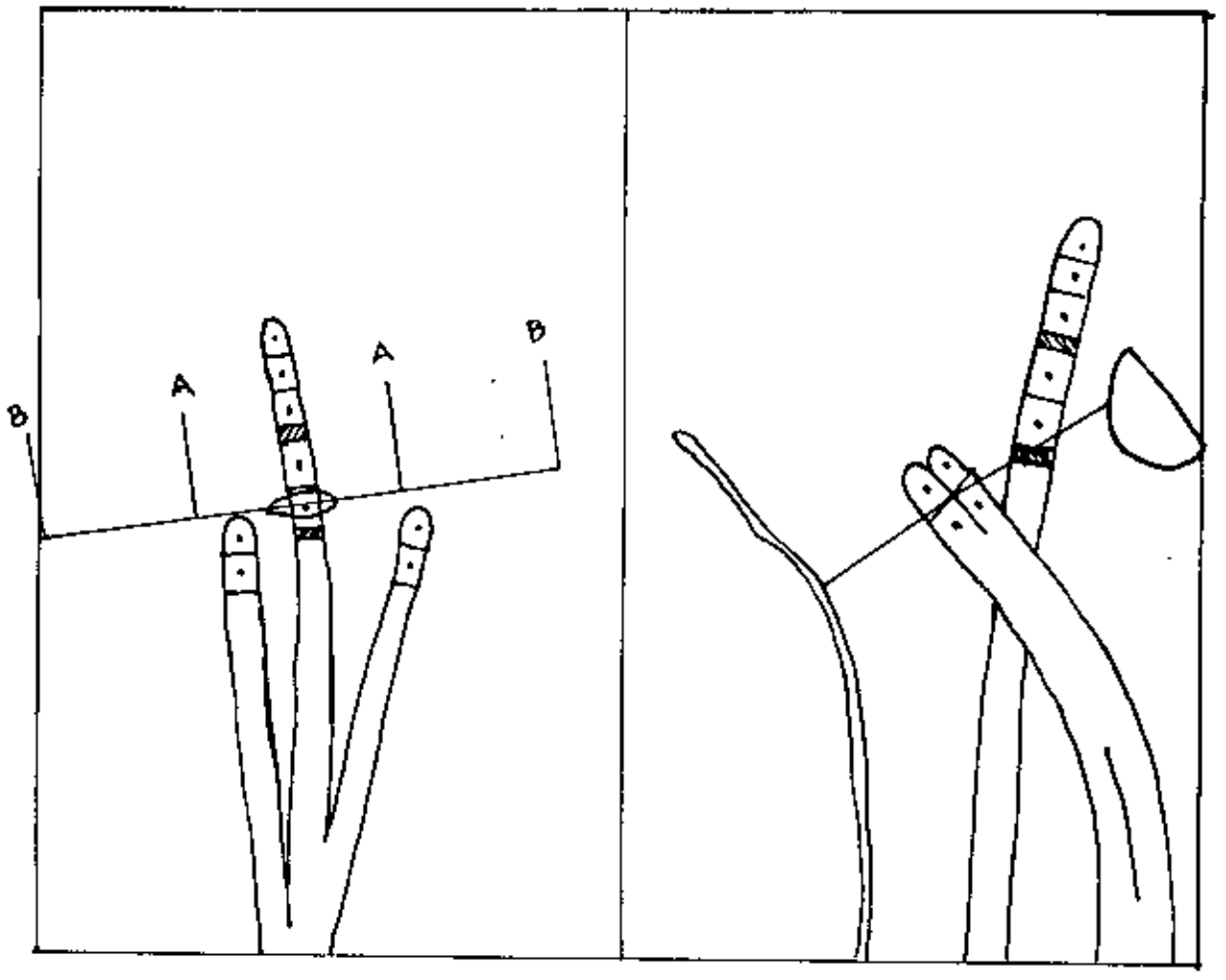


Fig 7.4: (a) AP and (b) Lateral X-ray radiograph of patient no-4

Case -5:

Date: 12.01 02

Name: Mrs. Sufia.
Age: 60
Reg no: 47/02

Prescribed dose at a = 2500 cGy

Diagnosis. CA cervix Stage II b

Total radioactivity:

Intracavitary Applicator: Uterine tube

360 mCi = 13.32 GBq

length – 5cm

Dose rate (cGy/ hr) = 124.63

Ovoid – 2cm

Total no of sources: 5+(2+2).

Total treatment time = 20.06 hr

Table 7.5: Calculation of absorbed dose at point A,point B, bladder reference point and rectum reference point of patient no-5.

Applicator	Source position no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Medium Uterine Tandem	1.	15.154	3.55	3.543	1.507
	2.	21.3	3.908	4.25	1.792
	3.	24.93	4.045	5.12	2.222
	4.	21.297	3.784	6.82	3.04
	5.	15.154	3.437	8.05	4.095
Near ovoid	6.	17.304	4.48	2.848	31.225
	7	10.136	3.908	2.848	31.225
Distant ovoid	8.	4	1.562	2.848	31.225
	9.	3.413	1.485	2.848	31.225
Total dose rate	_	132.69	30.16	39.171	137.556
Total dose (cGy)	_	2661.76	605	786	2759.4

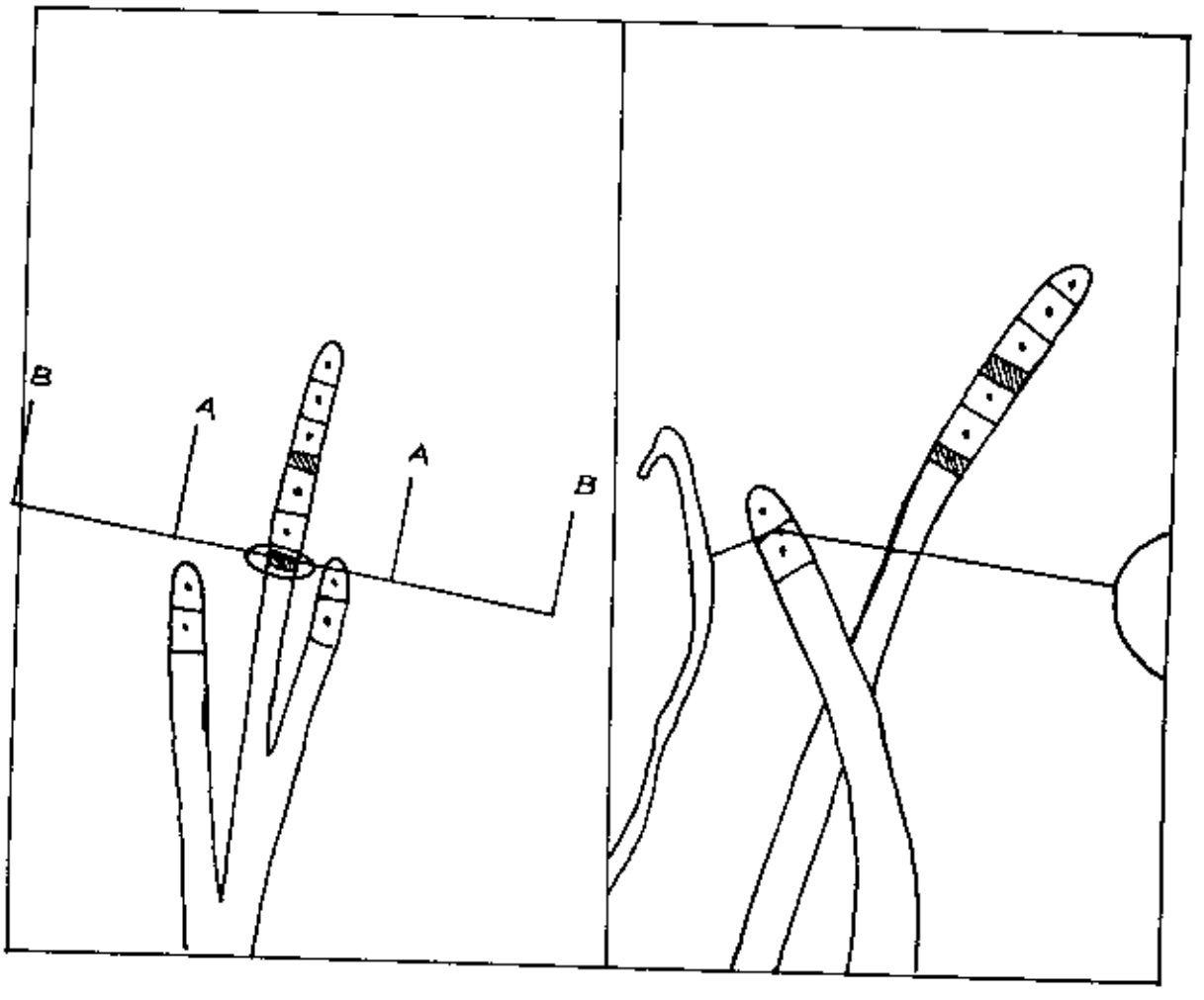


Fig 7.5: (a) AP and (b) Lateral X-ray radiograph of patient no-5

Case -6: Date: 23.12.01

Name: Mrs. Shamarunnessa.

Age: 50

Reg no: 1121/01

Diagnosis: CA cervix Stage II b

Intracavitary Applicator: Uterine tube length – 3.5cm

Ovoid – 2cm

Prescribed dose at 'A' = 2500 cGy

Total radioactivity:

360 mCi = 13.32 GBq

Dose rate (cGy/ hr) = 125

Total no of sources: 5+(2+2).

Total treatment time = 20hr

Table 7.6: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-6.

Applicator	Source position no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Medium Uterine Tandem	1.	23.05	4.11	7.75	2.71
	2.	25.01	4.11	10.8	3.42
	3.	21.315	4	14.95	4.265
	4.	14.95	3.6	22.27	6.33
	5.	9.378	3.19	23.95	8.5
Near ovoid	6.	13.93	5.38	8.883	11.98
	7.	8.82	4.11	8.883	11.98
Distant ovoid	8.	3.37	1.44	8.883	11.98
	9.	3.156	1.37	8.883	11.98
Total dose rate	_	122.97	31.31	115.25	73.13
Total dose (cGy)	_	2459.40	626.2	2305	1462.7

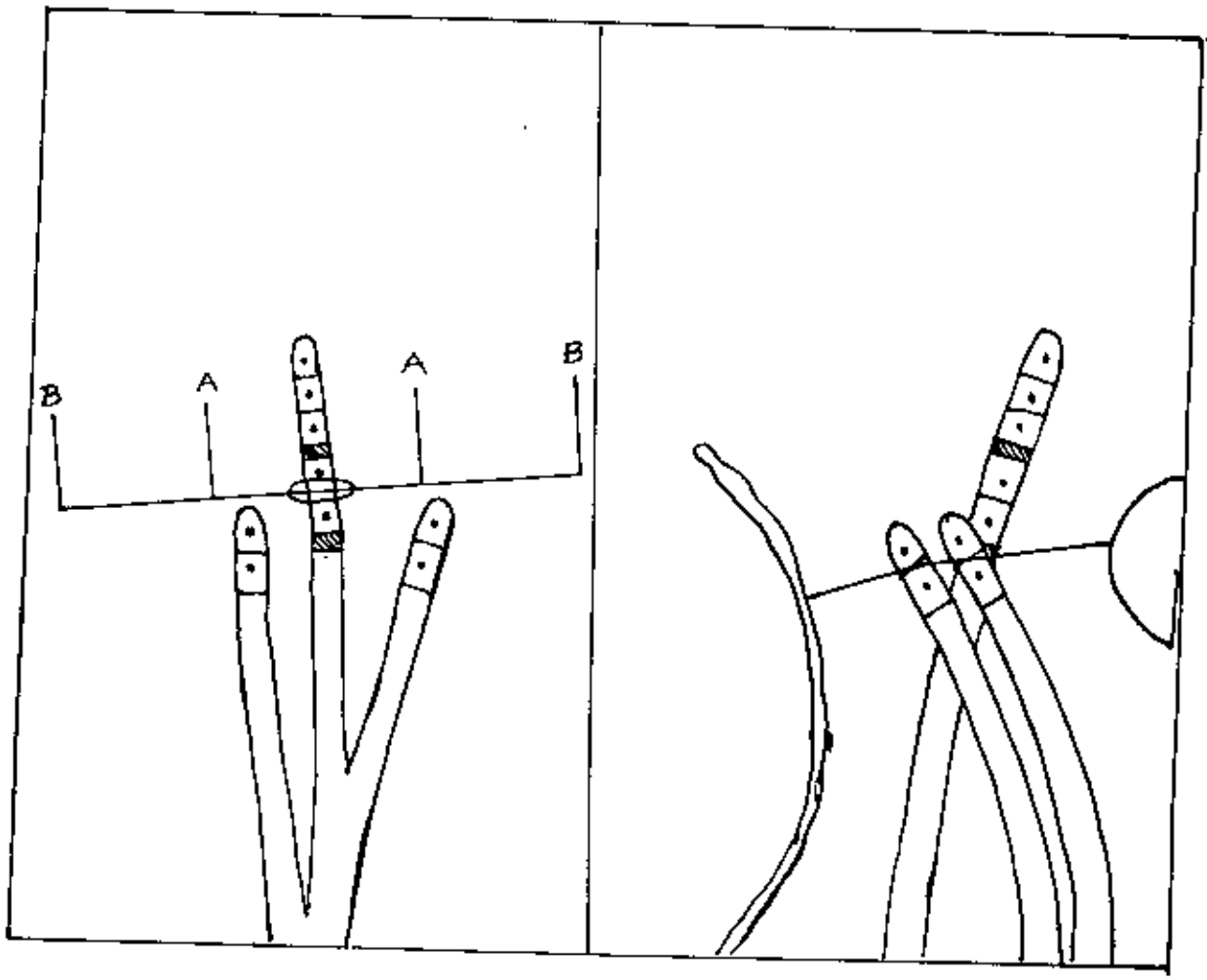


Fig 7.6: (a) AP and (b) Lateral X-ray radiograph of patient no-6

Case -7:

Date: 05.11.01

Name: Mrs. Sabeha Khatun.

Age: 65

Reg no: 1374/01

Diagnosis: CA cervix Stage III b

Intracavitary Applicator: Uterine tube length – 4cm

Ovoid – 2cm

Prescribed dose at 'A' = 3000 cGy

Total radioactivity:

360 mCi = 13.32 GBq

Dose rate (cGy/ hr) = 124.48

Total no of sources: 5+(2+2).

Total treatment time = 24.1hr

Table 7.7: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-7.

Applicator	Source position no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Medium Uterine Tandem	1.	20.83	4.1	7.51	2.154
	2.	24.8	4.0	10.93	2.62
	3.	22.29	4.1	16.14	3.27
	4.	16.05	3.68	28.26	4.45
	5.	11.59	3.38	40.03	6.92
Near ovoid	6.	12.85	4.73	10.57	10.95
	7.	7.69	3.68	10.57	10.95
Distant ovoid	8.	4.26	1.65	10.57	10.95
	9.	3.74	1.57	10.57	10.95
Total dose rate	_	124.1	31.054	145.14	63.206
Total dose (cGy)	_	2990.81	748.4	3498	1523.3

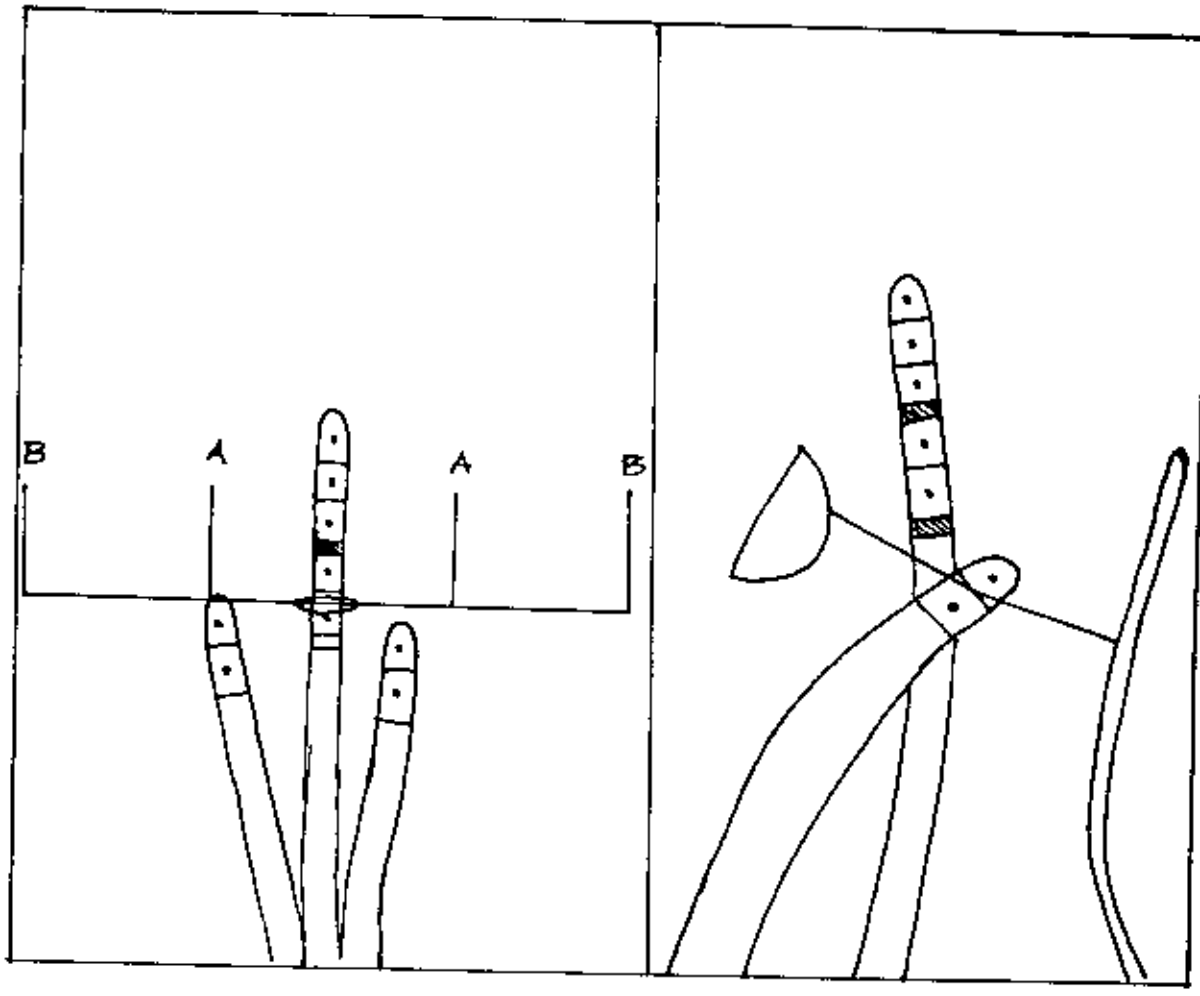


Fig 7.7: (a) AP and (b) Lateral X-ray radiograph of patient no-7

Case -8: Date: 08.10.01

Name: Mrs. Tahmina Begum.

Age: 55

Reg no: 1193/01

Diagnosis: CA cervix Stage III b

Intracavitary Applicator: Uterine tube length – 5cm

Ovoid – 2cm

Prescribed dose at 'A' = 3000 cGy

Total radioactivity:

360 mCi = 13.32 GBq

Dose rate (cGy/ hr) = 125

Total no of sources: 5+(2+2).

Total treatment time = 24hr

Table 7.8: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-8.

Applicator	Source position no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Medium Uterine Tandem	1.	16.84	3.82	3.71	1.57
	2.	21.81	3.94	4.77	1087
	3.	25.16	4.08	6.35	2.30
	4.	21.81	3.94	10.09	3.24
	5.	15.86	3.70	14.43	4.20
Near ovoid	6.	17.91	5.94	7.55	15.43
	7.	10.80	7.79	7.55	15.43
Distant ovoid	8.	4.017	1.61	7.55	15.43
	9.	3.34	1.51	7.55	15.43
Total dose rate	_	137.552	33.33	69.56	74.9
Total dose (cGy)	_	3301.25	800	1669	1798

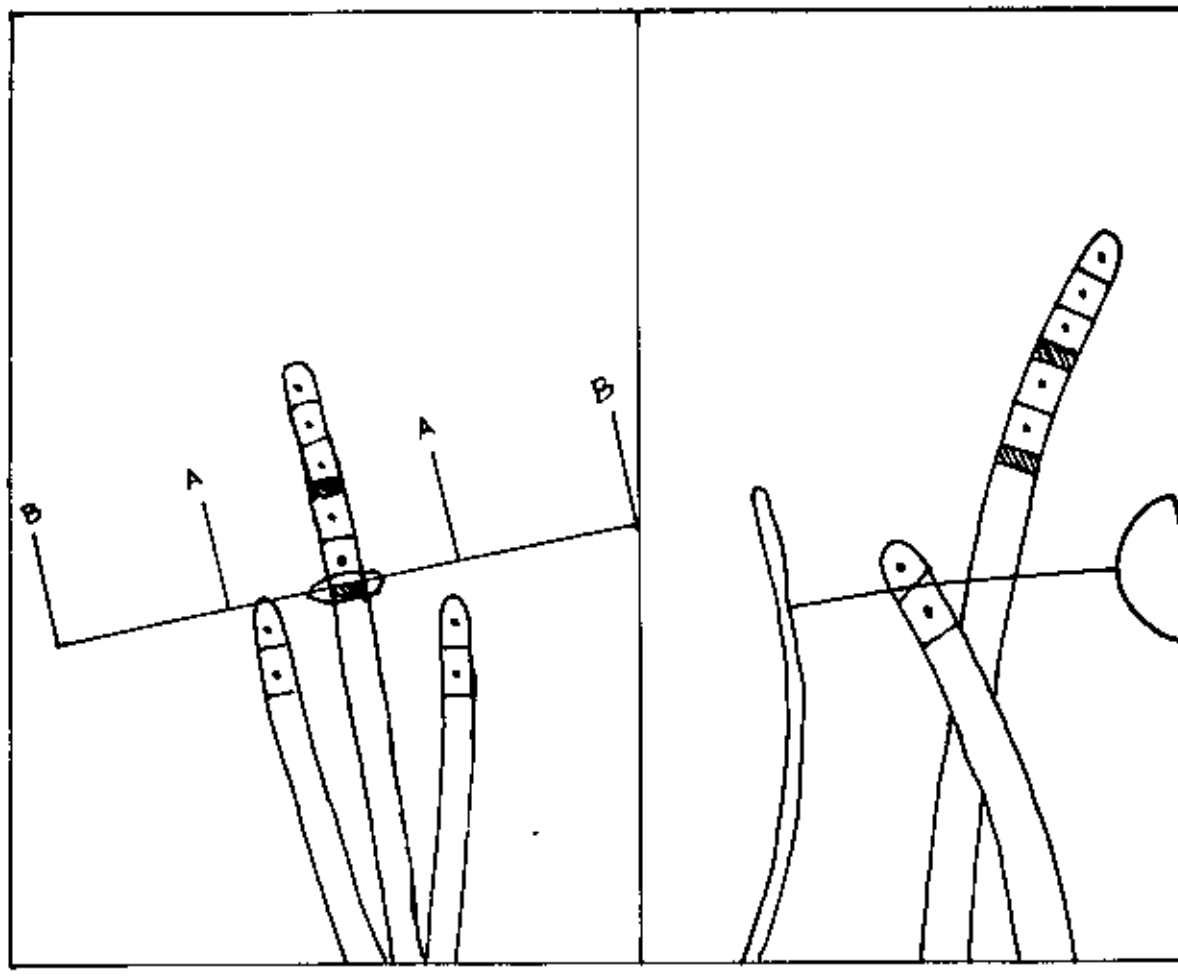


Fig 7.8: (a) AP and (b) Lateral X-ray radiograph of patient no-8

Case -9: Date: 15.09 01

Name: Mrs. Panna

Age: 50

Reg no: 01/888

Diagnosis: CA cervix, Stage II b

Intracavitary Applicator: Uterine tube length – 3.5cm

Ovoid – 2cm

Prescribed dose at 'A' = 2430 cGy

Total radioactivity:

360 mCi = 13.32 GBq

Dose rate (cGy/ hr) = 125

Total no of sources: 5+(2+2).

Total treatment time = 19.92hr

Table 7.9: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-9.

Applicator	Source position no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Medium Uterine Tandem	1.	23.317	4	5.13	3.11
	2.	25.145	4	6.93	4.05
	3.	23.317	4	9.06	5.13
	4.	14.63	3.53	14.22	7.47
	5.	10	3.14	18.79	9.84
Near ovoid	6.	13.736	4.58	9.39	17.63
	7.	8.6	3.9	9.39	17.63
Distant ovoid	8.	4.75	1.71	9.39	17.63
	9	3.846	1.63	9.39	17.63
Total dose rate	_	127.34	30.5	91.67	100.11
Total dose (cGy)	_	2536.6	607.4	1826	1994.2

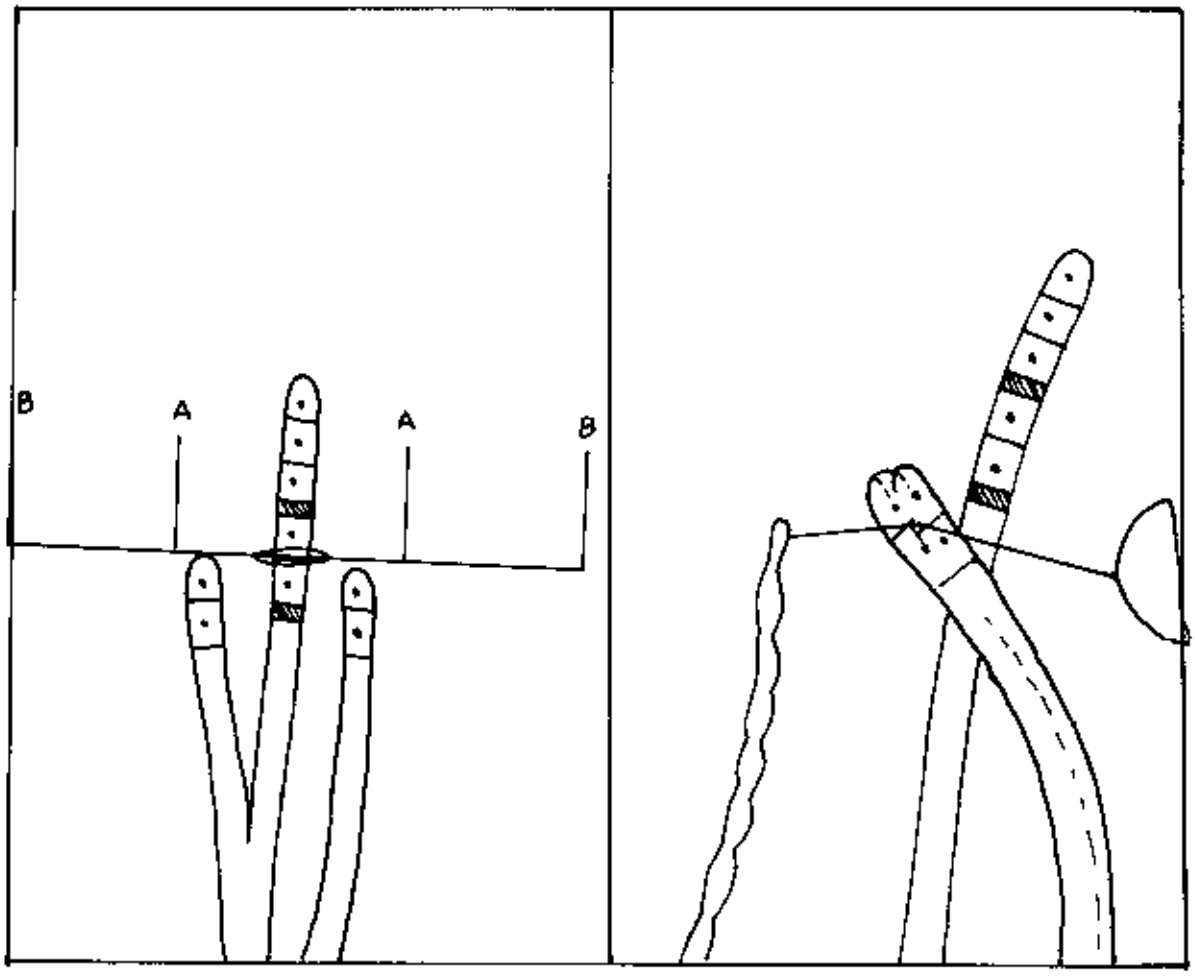


Fig 7.9: (a) AP and (b) Lateral X-ray radiograph of patient no-9

Case -10: Date: 03 09 01

Name: Mrs. Hasna begum.

Age: 55 yr's.

Reg no: 937/01

Diagnosis: CA cervix Stage II b

Intracavitary Applicator: Uterine tube length – 5cm

Ovoid – 2cm

Prescribed dose at 'A' = 2500 cGy

Total radioactivity:

360 mCi = 13.32 GBq

Dose rate (cGy/ hr) = 125

Total no of sources: 5+(2+2).

Total treatment time = 19.92hr's

Table 7.10: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-10.

Applicator	Source position No	Calculated dose at point A. (cGy/hr)	Calculated dose at point B (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Medium Uterine Tandem	1.	10 73	3.21	3.72	1.82
	2.	14 75	3.55	5.05	2.19
	3.	21.23	3.80	6.71	2.68
	4.	25.09	3.94	11.23	3.83
	5.	21.24	3.80	17.14	5.05
Near ovoid	6.	10.03	4.76	11.79	15.43
	7.	7.04	3.80	11.79	15.43
Distant ovoid	8.	4.15	1.69	11.79	15.43
	9.	3.21	1.52	11.79	15.43
Total dose rate	_	117.476	30.1	91.03	77.297
Total dose (cGy)	_	2340.12	599.6	1813.3	1539.8

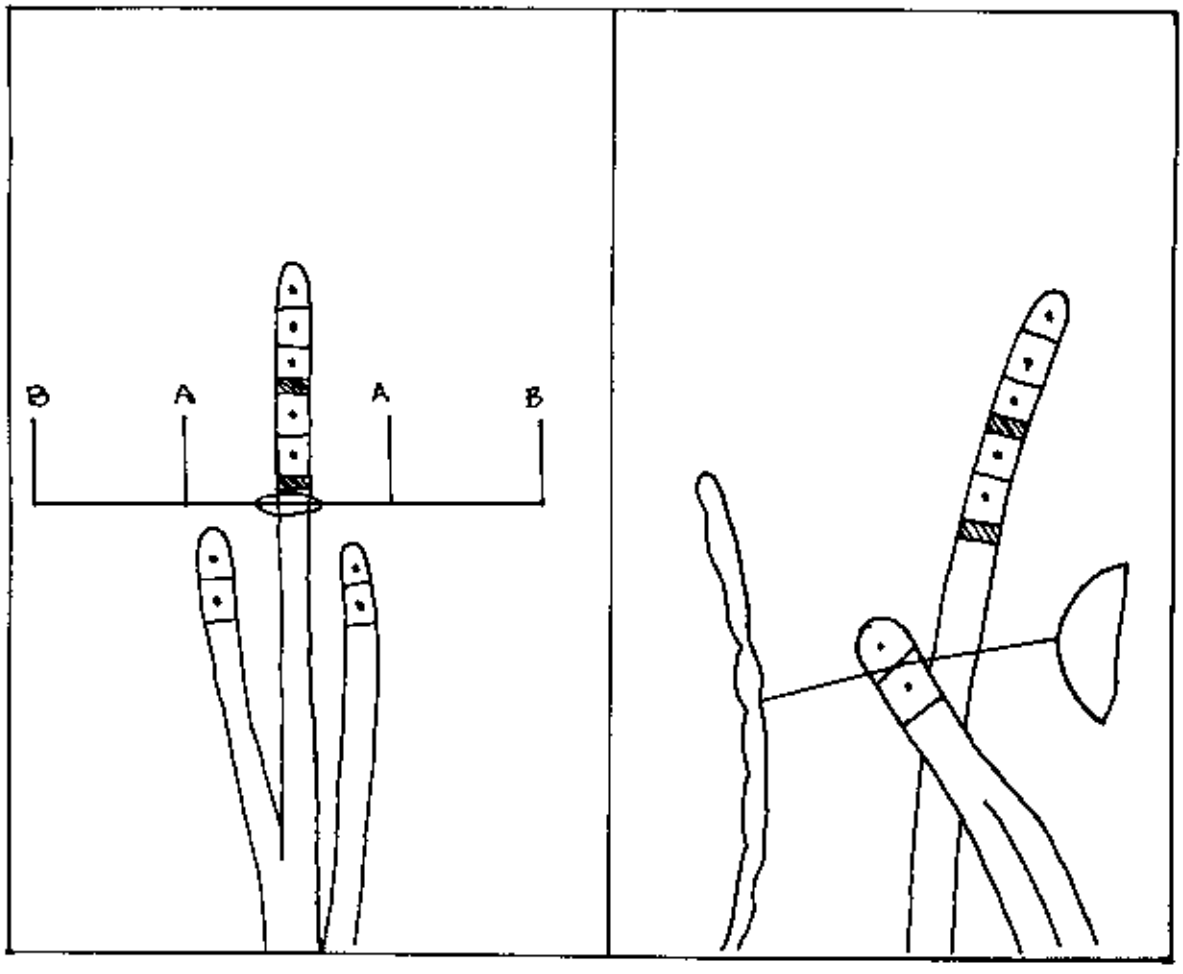


Fig 7.10: (a) AP and (b) Lateral X-ray radiograph of patient no-10

Case -11: Date: 21.08.01

Name: Mrs. Sufia Begum

Age: Not mentioned.

Reg no: 540/01

Diagnosis: CA cervix Stage III b

Intracavitary Applicator: Uterine tube length – 6 cm

Ovoid – 2cm

Prescribed dose at 'A' = 2500 cGy

Total radioactivity:

440 mCi = 16.28 GBq

Dose rate (cGy/ hr) = 138.28

Total no of sources: 7+(2+2).

Total treatment time = 18.08 hr

Table 7.11: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-11.

Applicator	Source position no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B. (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Long Uterine Tandem	1.	6.6	2.66	2.88	1.63
	2.	8.89	2.92	3.59	1.99
	3.	12.6	3.33	4.62	2.39
	4.	19.29	3.72	6.61	3.39
	5.	24.65	3.87	8.87	4.48
	6.	20 84	3 87	13 26	6 84
	7.	15.35	3.59	16.80	9.28
Near Ovoid	8.	11.22	4.17	10 78	14.96
	9.	7.24	3.44	10.78	14.96
Distant ovoid	10.	3.50	1.49	10.78	14.96
	11.	3.03	1.39	10.78	14.96
Total dose rate	_	133.224	34.5	99.75	89.843
Total dose (cGy)	_	2408.68	623	1803	1624.36

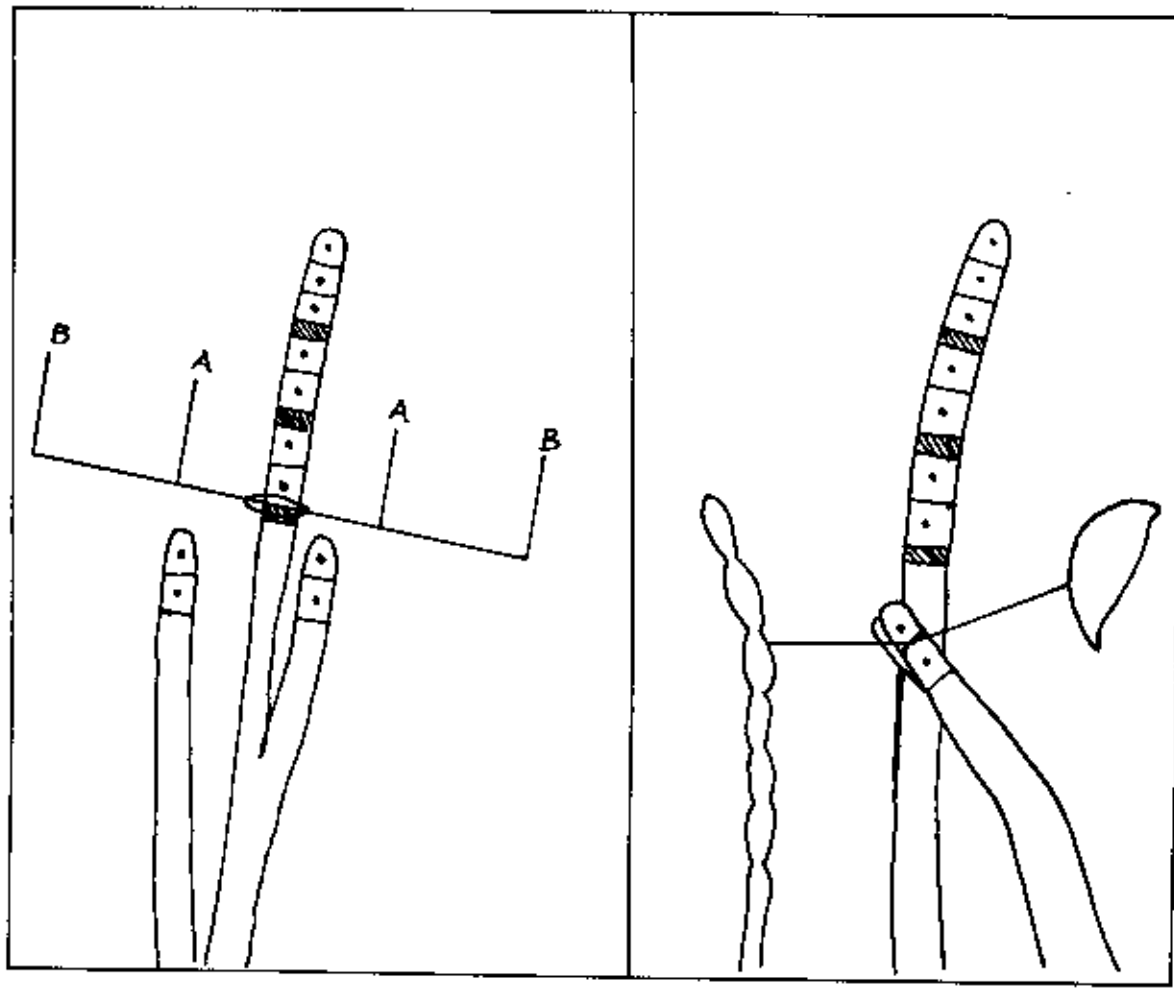


Fig 7.11: (a) AP and (b) Lateral X-ray radiograph of patient no-11

Case -12:

Date: 01.08.01

Name: Mrs. Nurun Nahar

Age: 50,

Reg no: 898/01

Diagnosis: CA cervix Stage II b

Intracavitary Applicator: Uterine tube length – 6 cm

Ovoid – 2cm

Prescribed dose at 'A' = 3000 cGy

Total radioactivity:

440 mCi = 16.28 GBq

Dose rate (cGy/ hr) = 138.25

Total no of sources: 7+(2+2).

Total treatment time = 21.7 hr

Table 7.12: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-12.

Applicator	Source position no	Calculated dose at point A (cGy/hr)	Calculated dose at point B. (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Long Uterine Tandem	1.	4.98	2.43	2.14	1.023
	2	6.42	2.82	2.63	1.223
	3.	9.04	3.22	3.30	1.452
	4.	14.66	3.68	4.70	1.862
	5.	21.32	3.83	6.22	2.4
	6.	24.13	4.14	9.36	3.283
	7.	19.71	3.68	13.19	4.27
Near ovoid	8.	10.18	4.14	6.33	18.955
	9.	6.48	3.32	6.33	18.955
Distant ovoid	10.	4.49	1.80	6.33	18.955
	11.	3.71	1.60	6.33	18.955
Total dose rate	_	125.11	34.662	66.86	91.33
Total dose (cGy)	_	2715	752.2	1451	1982

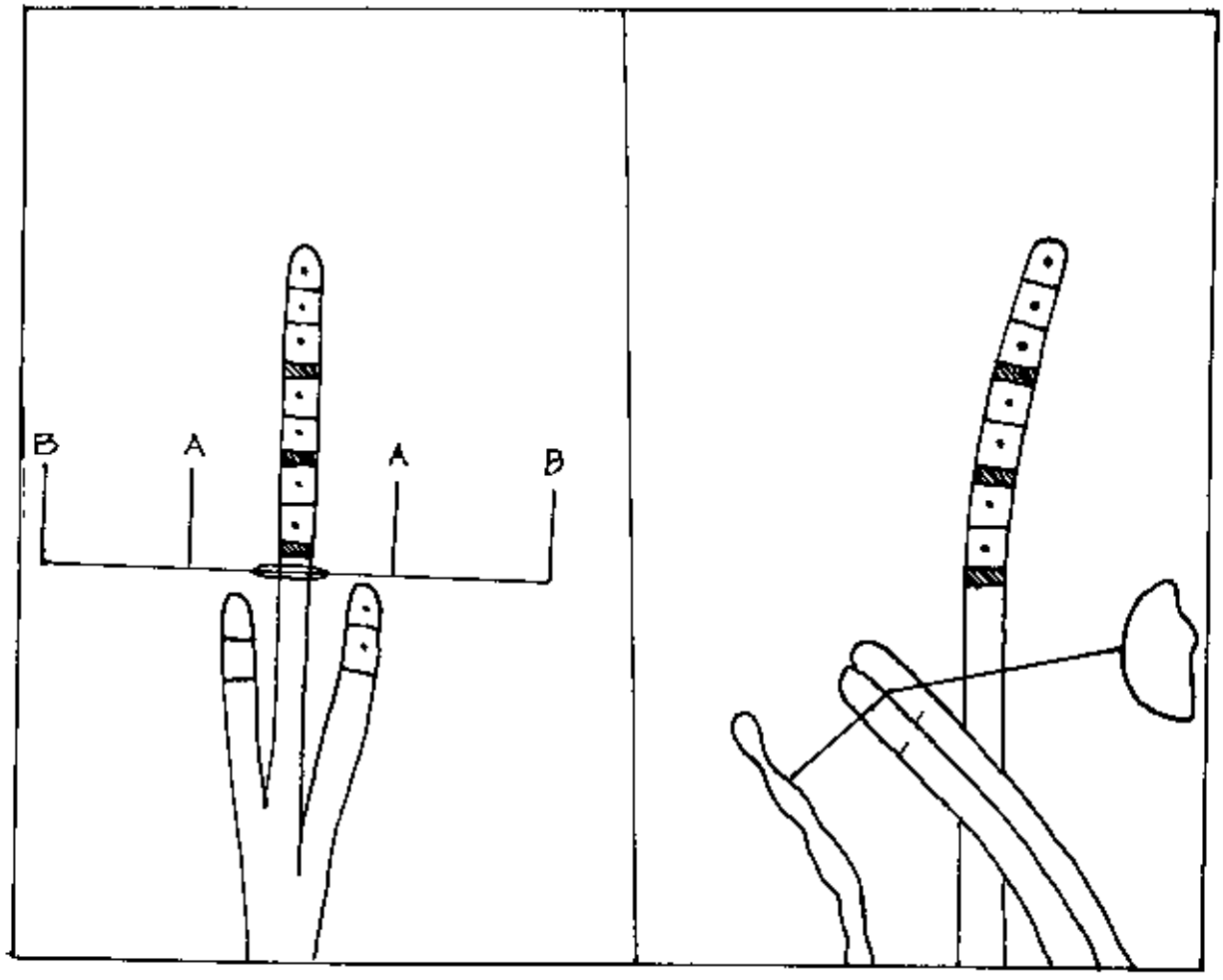


Fig 7.12: (a) AP and (b) Lateral X-ray radiograph of patient no-12

Case -13:

Date: 21.07.01

Name: Mrs Yasmin.

Age: 38 yr's

Reg no: 697/01

Diagnosis: CA cervix Stage II b

Intracavitary Applicator: Uterine tube length –5cm

Ovoid – 2cm

Prescribed dose at 'A' = 2500 cGy

Total radioactivity:

360 mCi = 13.32 GBq

Dose rate (cGy/ hr) = 125.94

Total no of sources: 5+(2+2).

Total treatment time = 19.85 hr

Table 7.13: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-13.

Applicator	Source position no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Medium Uterine Tandem	1.	8.43	3.27	3.28	1.7
	2.	11.91	4.04	4.15	1.99
	3.	15.50	3.884	5.39	2.46
	4.	24.75	4.04	8.54	3.46
	5.	27.05	4. 04	12.52	4.56
Near ovoid	6.	15.50	4.89	8.97	16.91
	7.	8.88	4.04	8.97	16.91
Distant ovoid	8.	3.64	1.436	8.97	16.91
	9.	3.05	1.367	8.97	16.91
Total dose rate	_	118.714	31	69.76	81.8
Total dose (cGy)	_	2356.5	615.5	1384.74	1624

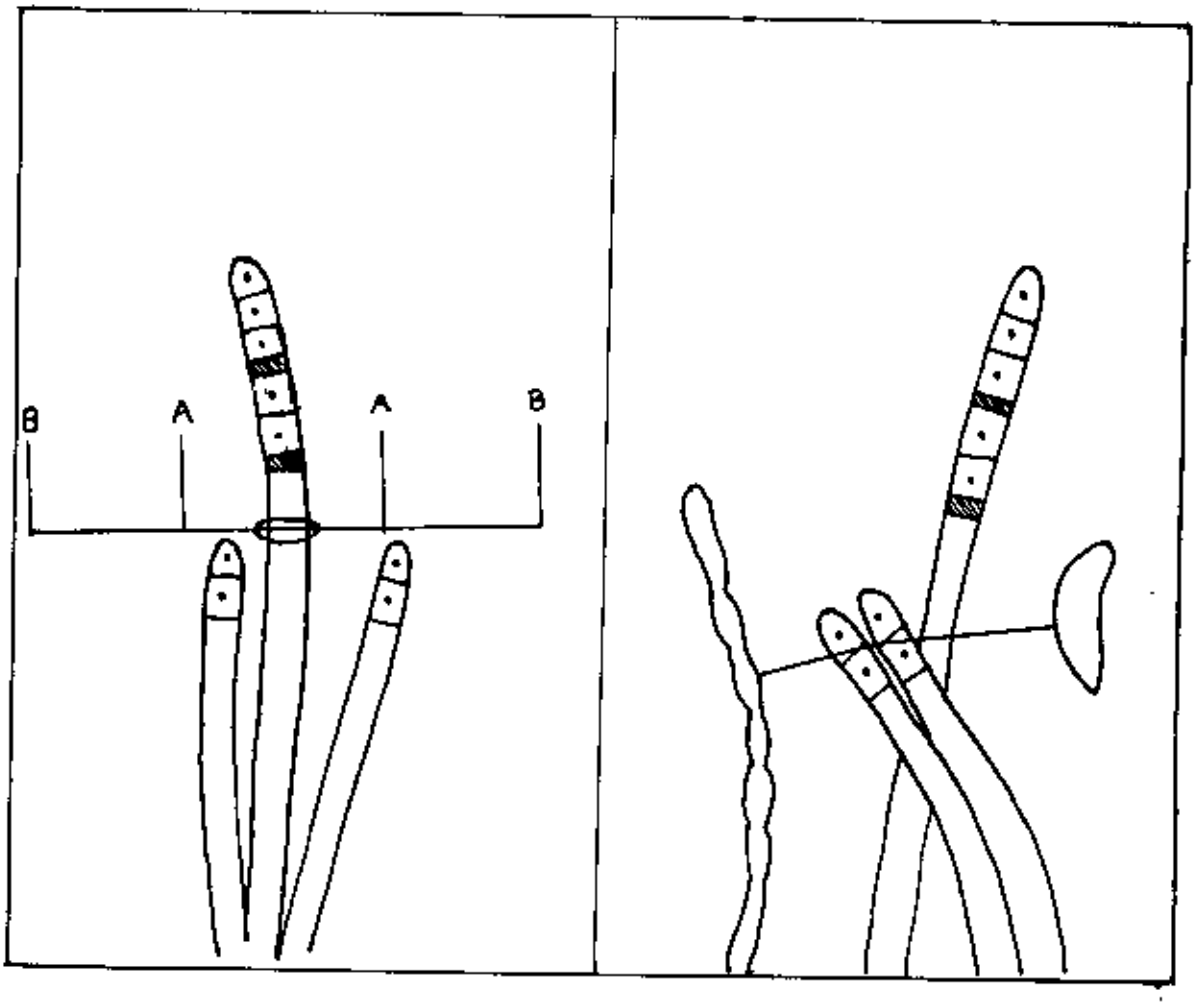


Fig 7.13: (a) AP and (b) Lateral X-ray radiograph of patient no-13

Case -14:

Date: 28.02.01

Name: Mrs. Maymena begum.

Age: 65 yr's

Reg no: 97/01

Diagnosis: CA cervix Stage II b

Intracavitary Applicator: Uterine tube length – 6 cm

Ovoid – 2cm

Prescribed dose at 'A' = 3000 cGy

Total radioactivity:

440 mCi = 16.28 GBq

Dose rate (cGy/ hr) = 139.86

Total no of sources: 7+(2+2).

Total treatment time = 21.45 hr's

Table 7.14: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-14.

Applicator	Source position no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B. (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Long Uterine Tandem	1.	6.34	2.42	2.02	1.18
	2.	8.83	2.82	2.40	1.38
	3.	11.69	3.25	2.86	1.68
	4.	18.82	3.67	3.82	2.27
	5.	23.82	3.98	4.58	2.88
	6.	21.95	3.98	6.16	4.18
	7.	15.09	3.67	7.13	5.18
Near ovoid	8.	12.47	5.11	3.98	14.38
	9.	7.62	3.98	3.98	14.38
Distant ovoid	10.	4.62	1.84	3 98	14.38
	11.	3.67	1.65	3.98	14.38
Total dose rate	–	134.92	36.37	44.9	76.26
Total dose (cGy)	–	2894	780.2	963	1636

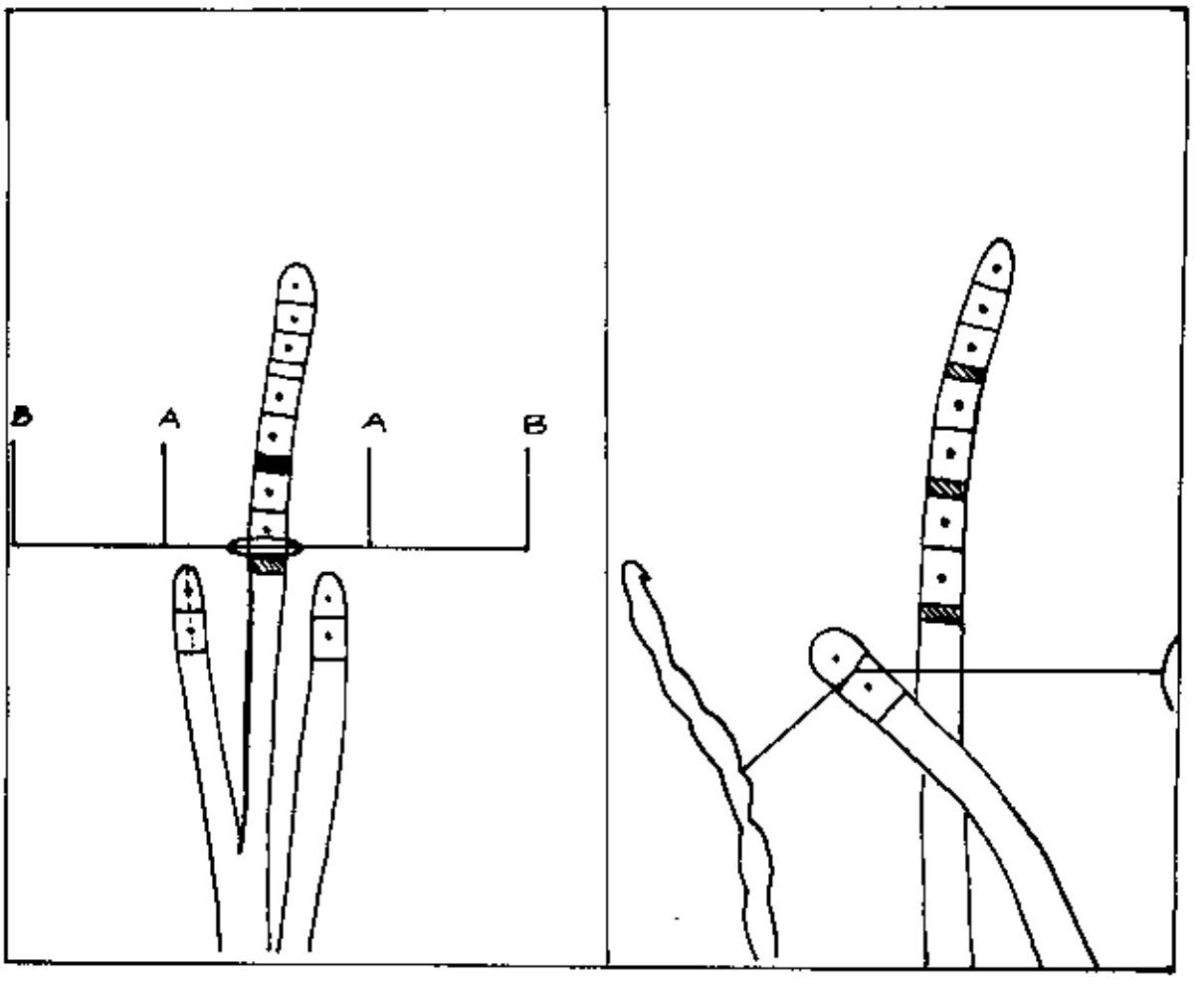


Fig 7.14: (a) AP and (b) Lateral X-ray radiograph of patient no-14

Case -15:

Date: 23.01.01

Name: Mrs Momtaz Begum.

Age: 50 yr's.

Reg no: 00/1263

Diagnosis: CA cervix Stage II b

Intracavitary Applicator: Uterine tube length – 5cm

Ovoid – 2.5 cm

Prescribed dose at 'A' = 2500 cGy

Total radioactivity:

360 mCi = 13.32 GBq

Dose rate (cGy/ hr) = 126.96

Total no of sources: 5+(2+2).

Total treatment time = 19.68hr's

Table 7.15: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-15.

Applicator	Source position no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Medium Uterine Tandem	1.	9.99	3.17	2.99	1.26
	2.	15.35	3.49	3.83	1.50
	3.	20.65	3.868	5.08	1.85
	4.	25.28	4.015	7.63	2.37
	5.	22.33	4.015	10.87	3.07
Near ovoid	6.	22.33	7.397	5.31	9.66
	7.	12.31	5.52	5.31	9.66
Distant ovoid	8.	5.55	1.87	5.31	9.66
	9.	4.51	1.716	5.31	9.66
Total dose rate	–	138.3	35.061	51.64	48.69
Total dose (cGy)	–	2722	690	1016.3	958.22

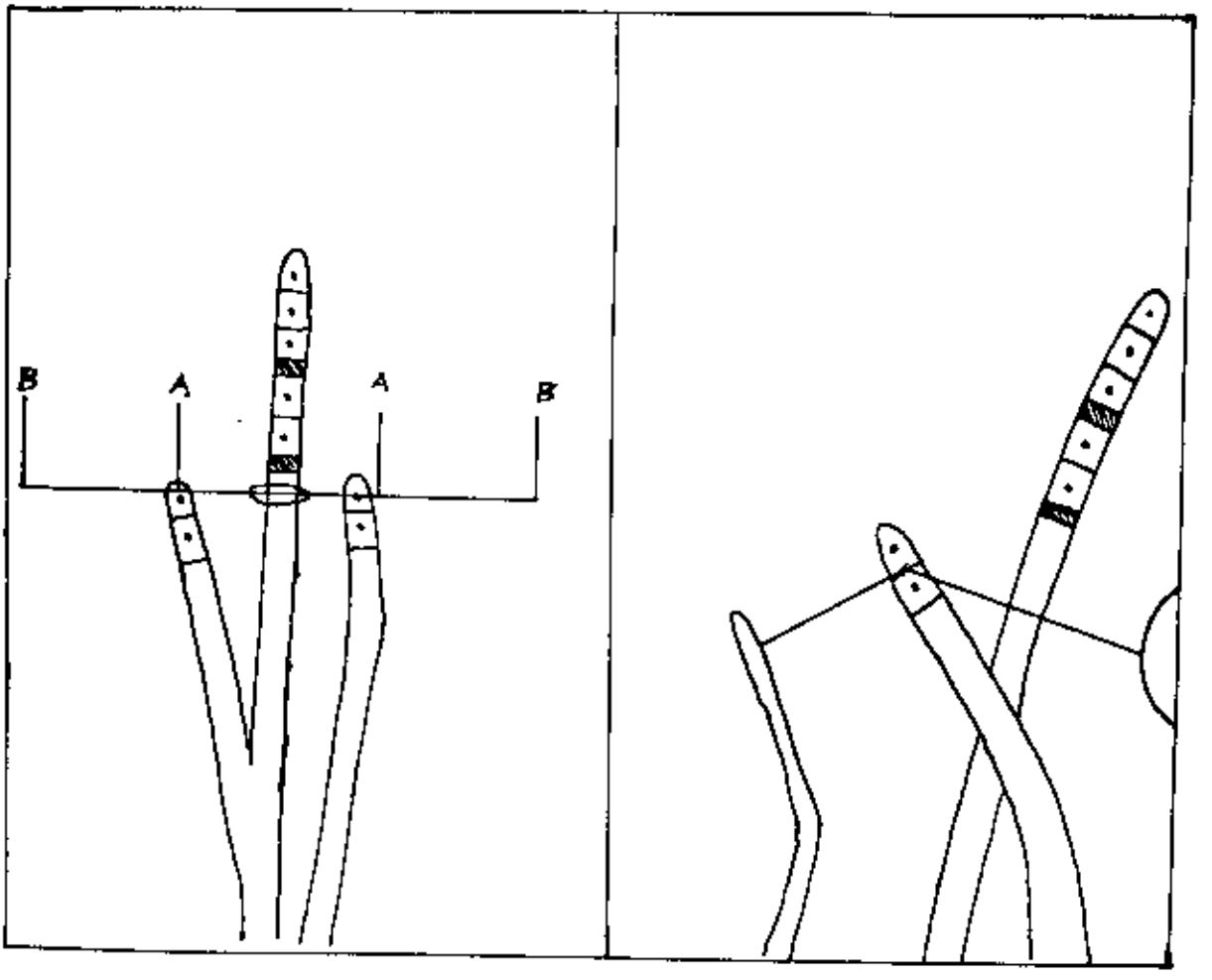


Fig 7.15: (a) AP and (b) Lateral X-ray radiograph of patient no-15

Case -16: Date: 24.10.00

Name: Mrs. Monowara.

Age: 45yr's.

Reg no: 00/1082

Diagnosis: CA cervix Stage III b

Intracavitary Applicator: Uterine tube length – 5cm

Ovoid – 2cm

Prescribed dose at 'A' = 2578 cGy

Total radioactivity:

360 mCi = 13.32 GBq

Dose rate (cGy/ hr) = 127.82

Total no of sources: 5+(2+2).

Total treatment time = 20.16 hr

Table 7.16: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-16.

Applicator	Source position no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Medium Uterine Tandem	1.	12.67	3.96	10.33	2.38
	2.	17.54	4.40	15.95	3.08
	3.	23.69	4.74	26.91	3.99
	4.	25.73	4.93	54.78	5.89
	5.	20.25	4.74	61.16	8.75
Near ovoid	6.	9.12	4.93	12.775	17.94
	7.	5.77	3.70	12.775	17.94
Distant ovoid	8.	4.30	1.94	12.775	17.94
	9.	3.23	1.66	12.775	17.94
Total dose rate	_	122.3	35	220.22	95.86
Total dose (cGy)	_	2465.6	705.6	4439	1932

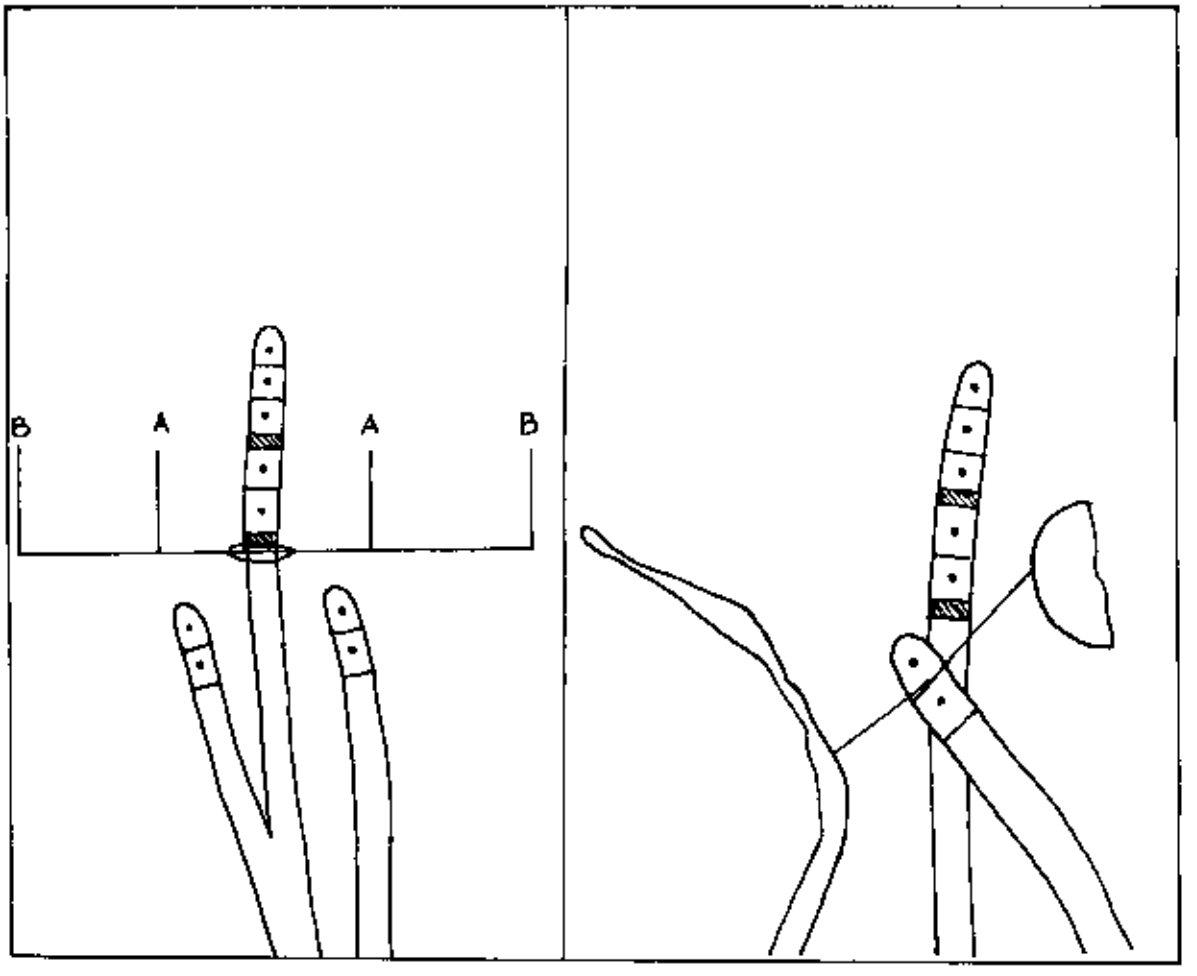


Fig 7.16: (a) AP and (b) Lateral X-ray radiograph of patient no-16

Case -17:

Date: 07.10.00

Age: 32 yr's.

Reg no: 2000/948

Diagnosis: CA cervix Stage II b

Intracavitary Applicator: Uterine tube length – 6 cm

Ovoid – 2.5cm

Prescribed dose at 'A' = 3500 cGy

Total radioactivity:

440 mCi = 16.28 GBq

Dose rate (cGy/ hr) = 140.96

Total no of sources: 7+(2+2).

Total treatment time = 24.83 hr

Table 7.17: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-17.

Applicator	Source position no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B. (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Long Uterine Tandem	1.	7.28	3.12	1.98	0.98
	2.	10.27	3.41	2.40	1.15
	3.	14.55	3.77	2.98	1.34
	4.	24.08	4.03	4.23	1.79
	5.	26.13	4.03	5.75	2.23
	6.	20.65	3.77	9.08	3.04
	7.	13.68	3.41	13.67	3.83
Near ovoid	8.	13.68	4.65	7.64	11.38
	9.	8.77	3.92	7.64	11.38
Distant ovoid	10.	3.77	1.54	7.64	11.38
	11.	3.28	1.50	7.64	11.38
Total dose rate	–	146.13	37.16	70.65	59.88
Total dose (cGy)	–	3628.5	922.65	1754	1487

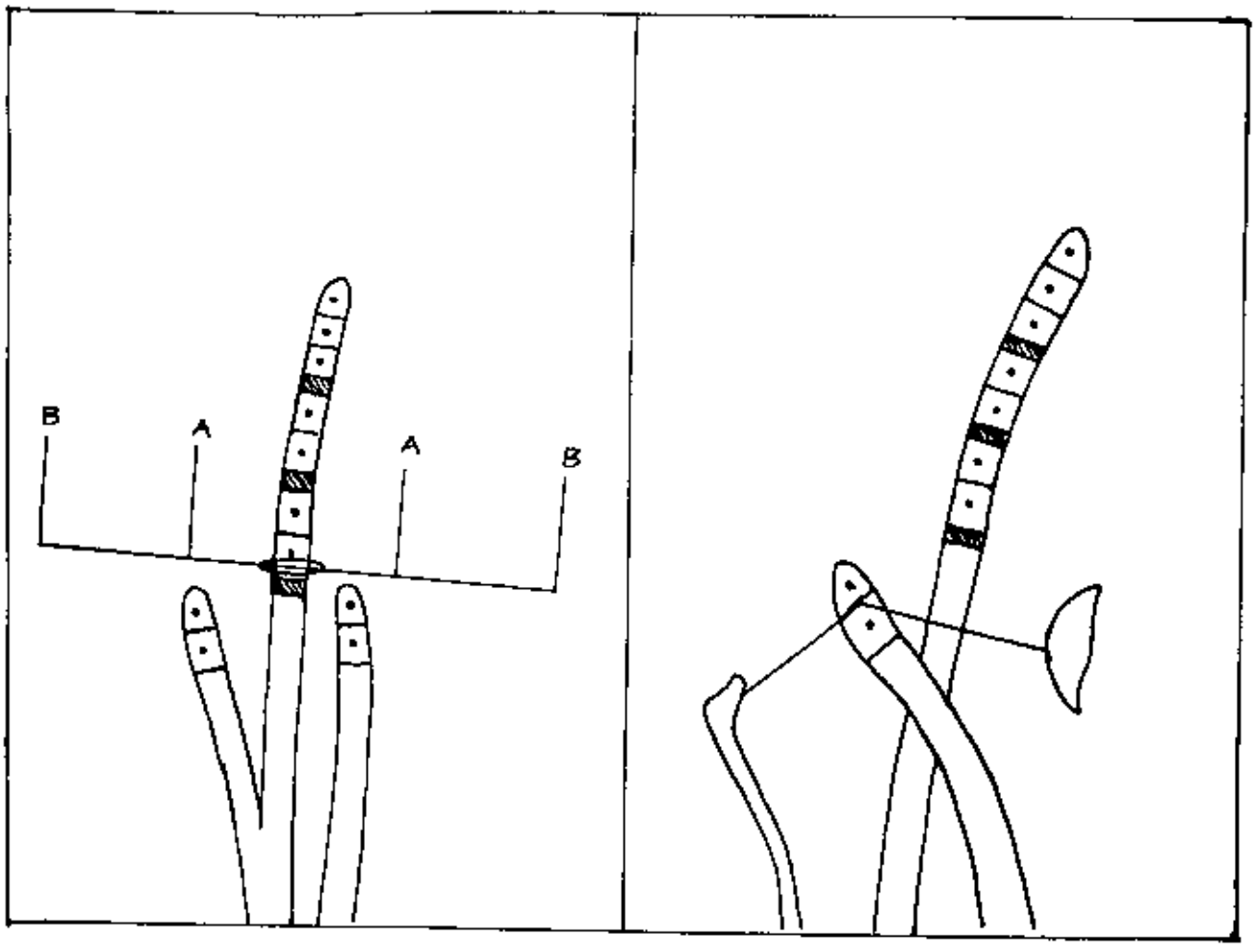


Fig 7.17: (a) AP and (b) Lateral X-ray radiograph of patient no-17

Case -18: Date: 18.09.00

Name: Mrs Zarina.

Age: 32 yr's.

Reg no: 2000/948

Diagnosis: CA cervix Stage II b

Intracavitary Applicator: Uterine tube length – 6 cm

Ovoid – 2.5cm

Prescribed dose at 'A' = 3453 cGy

Total radioactivity:

440 mCi = 16.28 GBq

Dose rate (cGy/ hr) = 140.94

Total no of sources: 7+(2+2).

Total treatment time = 24.50

Table 7.18: Calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point of patient no-18.

Applicator	Source positron no	Calculated dose at point A. (cGy/hr)	Calculated dose at point B. (cGy/hr)	Dose at bladder reference point (cGy/hr)	Dose at rectum reference point (cGy/hr)
Long Uterine Tandem	1.	6.07	2.61	1.71	0.84
	2.	8.05	3.03	2.12	0.98
	3.	11.72	3.45	2.56	1.15
	4.	18.77	3.96	3.46	1.52
	5.	24.00	4.11	4.70	1.91
	6.	22.12	3.96	6.88	2.63
	7.	16.27	3.69	9.50	3.32
Near ovoid	8.	20.45	6.92	4.75	5.92
	9.	11.17	5.36	4.75	5.92
Distant ovoid	10.	4 66	1.68	4.75	5.92
	11.	3.80	1.62	4.75	5.92
Total dose rate	_	147.08	40.39	50	36
Total dose (cGy)	_	3603.65	990	1223.5	882.4

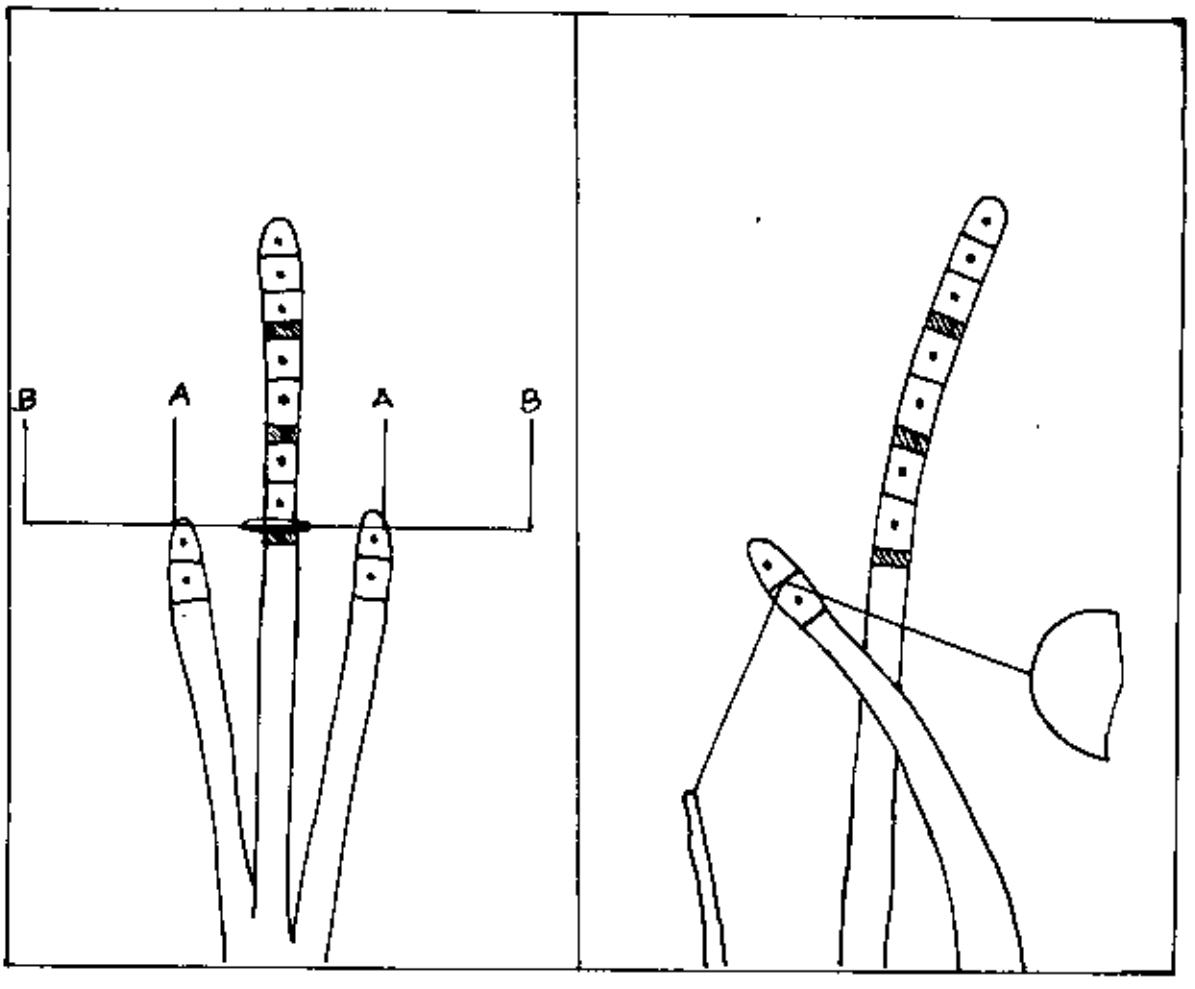


Fig 7.18: (a) AP and (b) Lateral X-ray radiograph of patient no-18

Table: 7.19

Percentage variation of calculated dose at point 'A' with the prescribed dose (Supplhers value) at the same point

Patients no.	Date	Stage	Prescribed dose at 'A' (cGy).	Calculated dose at 'A' (cGy).	% Variation at point 'A'
1.	07.10.03	III b	2700	2770.00	+2.60
2.	19.03.02	IIb	2600	2566.17	-1.30
3.	02.01.02	IIb	3000	2983.85	-0.53
4.	19.01.02	IIb	2500	2522.80	+1.00
5.	12.01.02	IIb	2500	2661.76	+6.47
6.	23.12.01	IIb	2500	2459.00	-1.64
7.	05.11.01	IIIb	3000	2991.00	-0.30
8.	08.10.01	IIIb	3000	3301.00	+10.00
9.	15.09.01	IIb	2430	2536.60	+4.38
10.	03.09.01	IIb	2500	2340.00	-6.40
11.	21.08.01	IIIb	2500	2409.00	-3.65
12.	01.08.01	IIb	3000	2715.00	-9.50
13.	21.07.01	IIb	2500	2356.50	-5.74
14.	28.02.01	IIb	3000	2894.00	-3.53
15	23.01.01	IIb	2500	2722.00	+8.88
16.	24.10.00	IIIb	2578	2465.60	-4.36
17.	07.10.00	IIb	3500	3628.50	+3.67
18.	18.09.00	IIb	3453	3603.65	+4.36

Table: 7.20

Percentage variation of calculated dose at point 'B' with the suppliers stated value at the same point

Patients no.	Date	Stage	suppliers stated value at Point 'B' (CGy).	Calculated dose at 'B' (CGy).	% Variation at point 'B'
1.	07.10.03	III b	730.00	695	-5.13
2.	19 03.02	IIb	659.28	612	-7.72
3.	02.01.02	IIb	811.92	816	+0.50
4.	19.01.02	IIb	630 70	600	-5.12
5.	12.01.02	IIb	630.70	605	-4.25
6.	23.12.01	IIb	645.95	626	-3.19
7.	05.11.01	IIIb	760 65	748	-1.69
8.	08.10.01	IIIb	760.41	800	+4.95
9.	15.09.01	IIb	631.14	607	-3.98
10.	03.09.01	IIb	631.14	600	-5.19
11.	21.08.01	IIIb	676.51	623	-8.59
12.	01.08.01	IIb	811.97	752	-7.94
13.	21.07.01	IIb	633 81	616	-2.89
14.	28.02.01	IIb	811.98	780	-4.10
15.	23.01.01	IIb	633.23	690	+8.23
16	24.10.00	IIIb	653.64	705.6	+7.36
17.	07.10.00	IIb	947.14	923	-2.61
18.	18.09.00	IIb	934.14	990	+5.60

Table: 7.21

Percentage of calculated dose at point 'B' with the Calculated dose at point 'A'

Patients no.	Date	Stage	Calculated dose at 'A' (CGy).	Calculated dose at point 'B'	% Variation with calculated dose at 'A'
1.	07.10.03	III b	2770.00	695	25.09
2.	19.03.02	IIb	2566.17	612	23.85
3.	02.01.02	IIb	2983.85	816	27.35
4.	19.01.02	IIb	2522.80	600	23.78
5.	12.01.02	IIb	2661.76	605	22.73
6.	23.12.01	IIb	2459.00	626	25.46
7.	05.11.01	IIIb	2991.00	748	25.00
8.	08.10.01	IIIb	3301.00	800	24.23
9.	15.09.01	IIb	2536.60	607	23.93
10.	03.09.01	IIb	2340.00	600	25.64
11.	21.08.01	IIIb	2409.00	623	25.86
12.	01.08.01	IIb	2715.00	752	27.69
13.	21.07.01	IIb	2356.50	616	26.14
14.	28.02.01	IIb	2894.00	780	26.95
15.	23.01.01	IIb	2722.00	690	25.35
16.	24.10.00	IIIb	2465.60	705.6	28.55
17.	07.10.00	IIb	3628.50	923	25.44
18.	18.09.00	IIb	3603.65	990	27.47

Table: 7.22

Percentage of calculated dose at bladder reference point with the calculated dose at Point 'A '.

Patients no.	Date	Stage	Calculated dose at 'A' (CGy).	Calculated dose at Bladder reference point (CGy).	% of calculated dose at point 'A'
1.	07.10.03	III b	2770.00	1832.50	66.15
2.	19.03.02	IIb	2566.17	3867.20	150.69
3	02.01.02	IIb	2983.85	1830.00	61.33
4.	19.01.02	IIb	2522.80	4197.20	166.37
5.	12.01.02	IIb	2661.76	786.00	29.53
6	23.12.01	IIb	2459.00	2305.00	93.74
7.	05.11.01	IIIb	2991.00	3498.00	116.95
8.	08.10.01	IIIb	3301.00	1669.00	50.56
9.	15.09.01	IIb	2536.60	1826.00	71.98
10	03.09.01	IIb	2340.00	1813.30	77.49
11.	21.08.01	IIIb	2409.00	1803.50	74.86
12.	01.08.01	IIb	2715.00	1451.00	53.44
13.	21.07.01	IIb	2356.50	1384.74	58.76
14.	28.02.01	IIb	2894.00	963.00	33.27
15.	23.01.01	IIb	2722.00	1016.30	37.34
16.	24.10.00	IIIb	2465.60	4439.00	180
17.	07.10.00	IIb	3628.50	1754.14	48.34
18.	18.09.00	IIb	3603.65	1223.50	33.95

Table: 7.23

Percentage of calculated dose at rectum reference point with the calculated dose at point 'A '.

Patients no.	Date	Stage	Calculated dose at point 'A' (CGy).	Calculated dose at Rectum reference point (CGy).	% of calculated dose at point 'A'
1.	07.10.03	III b	2770.00	1267	45.74
2.	19.03.02	IIb	2566.17	1678	65.39
3.	02.01.02	IIb	2983.85	1337.73	44.83
4.	19.01.02	IIb	2522 80	975.39	38.66
5.	12.01.02	IIb	2661.76	2759 38	103.67
6.	23.12.01	IIb	2459.00	1462.7	59.48
7.	05.11.01	IIIb	2991.00	1523.27	50.93
8.	08.10.01	IIIb	3301.00	1798	54.46
9.	15.09.01	IIb	2536.60	1994.4	78.62
10.	03.09.01	IIb	2340.00	1539.75	65.80
11.	21.08.01	IIIb	2409.00	1624.36	67.43
12.	01.08.01	IIb	2715.00	1982	73.00
13.	21.07.01	IIb	2356.50	1624	68.91
14.	28.02.01	IIb	2894.00	1636	56.53
15.	23.01.01	IIb	2722.00	958	35.19
16.	24.10.00	IIIb	2465.60	1932	78.36
17.	07.10.00	IIb	3628 50	1487	40.98
18.	18.09.00	IIb	3603.65	882.41	24.48

DISCUSSION

In oncological unit of Delta medical centre Ltd. in case of brachytherapy treatment of cervical cancer patients, physician prescribed the A point dose prior insertion of the source. The medical physicist calculates the irradiation time using supplier's stated value. But as there is no computer facility for treatment planning and lack of adequate manpower, it is not possible to calculate the absorbed dose at point A and B. Manually the calculation process is very time consuming and complicated procedure. In Delta oncological unit, the rectum and bladder dose is calculated by the physicist using both the AP & lateral radiograph of the patient, which are taken after patient preparation with the applicator (without source), catheter and rectal marker filled with contrast media. If they find the rectum and bladder dose above the tolerance level, they inform it to the oncologists and based on this calculation the physician can make an immediate decision on whether or not to continue with the treatment or to modify with the application.

In brachytherapy dose distribution usually needs to be computed in planes related to the main direction of the implanted sources [47]. Based on this reference the dose rate and total dose of 18 patients dated from 18.09.00 to 07.10.03 was calculated at A, B, rectum and bladder reference point using Equation-1, stated in chapter-6. The results are summarized from Table- 7.1 to 7.23. The calculated and prescribed dose variation at point 'A' was found to be from –9.50% to +10% among 18 patients, which are shown in Table – 7.19. The Paterson- Parker and Manchester system was developed to deliver uniform dose (within ± 10%) to a plane or volume [48]. So the dose delivered at cervix cancer treatment in oncological unit of Delta Medical Centre, Dhaka, is compatible with the International standard.

Calculation of absorbed dose at point B is also done in this thesis work. The calculated and stated dose variation at point 'B' was found to be –8.59% to 8.23% among 18 patients, which are shown in Table-7.20. The coated value by the suppliers at point B is found to be 27 % of point A for long uterine tandem and ovoid sources and 25.35 % of point A for medium uterine tandem and ovoid sources. In this present study, the result for long uterine tandem and ovoid sources for 7 patients was found to be 25.09 % to 27.69 % of calculated dose at point A. In case of medium uterine

source the lowest value was 22.73% and highest value was 28.63% of calculated dose at point A, which are also comparable with the suppliers stated value [19] and also comparable with another research work done by A. A. El-Masry et al [12]. The paper presents the results of computer dosimetry of external beam and intracavitary irradiation in 50 patients with carcinoma of the uterine cervix in Alexandria University Hospital, Egypt. The extent of the tumour and the position of critical neighboring organs were determined for clinical dosimetry and their result at B point dose did not exceed 30- 40% of the dose at point A.

We also calculated the absorbed dose at bladder reference point and rectum reference point. As these two organs are the most critical organ in case of treatment of cervical cancer patient. The maximum dose to bladder and rectum should be as far as possible, less than the dose to point A (e. g. 80% or less of the dose to point A). However the dose distribution patterns will vary from patient to patient, depending on the vaginal packing, patient anatomy and the source geometry achieved. Owing to short treatment distance, the geometry of source distribution is critical [4].

In this present study, according to Table-7.22 and Table-7.23 it was found that, 13 out of 18 patients the dose at bladder reference point was below 80% and in case of 17 patients the dose at rectum reference point was below 80% of A point dose. In case of above 80% dose at bladder point (5 cases) it is observed that in every case the bladder was very near position to tandem source as found in the lateral view, which are shown in Fig- 7.2, 7.4, 7.6, 7.7 and 7.16. In case of above 80% dose at rectum reference point (1 case) it is observed that the ovoid sources was very near to the rectum reference point. This is shown in fig-7.5.

In last two cases the same patient was treated within one-week gap. But for nearly the same prescribed dose (3453 cGy and 3500 cGy) the bladder and rectum got the dose 1223 5 cGy (33.95 % of calculated dose at point A) and 882.41 cGy (24.48 % of calculated dose at point A) at the first insertion done on 18.09.00. The same patient's bladder and rectum dose were 1754.14 cGy (48.34 % of calculated dose at point A) and 1487 (40.98 % of calculated dose at point A) at the second insertion done on 07.10.00. The bladder and rectum dose at the second time increases to 43% and 68%

of the first time. This is because, the rectum and bladder distance (due to the vaginal packing) from the sources at the first time was greater than at the second time.

N. Petoussi et al [16] calculated the absorbed doses using Monte Carlo Calculation, resulting from radiotherapy treatment of cervical cancer to various organs and tissues in the body. It was a part of a large radiation study supported by world health organization and involves the follow – up of 30,000 women treated for cervical cancer. As an example they have shown some organ doses for three of the cases (case 1, case2 and case3) including the follow-up study of the WHO. From their study it was also found that, in case1, the patient was treated only by brachytherapy, the bladder dose was found to be 4515cGy, rectum dose for this patient was 1732 cGy. In second case the patient was treated with single ovoid plus external AP+PA fields, the bladder dose was found to be 5547 cGy, rectum dose 1767 cGy . In third case the patient was treated with ovoids, applicators plus split AP + PA fields, the bladder dose for that case was 8334 cGy and rectum dose was 2900CGy. In this thesis work the highest bladder dose was found to be 4439 cGy, which is less than that value found in first case and the highest rectum dose was found to be 2759 cGy.

The 18 patients, who were treated by brachytherapy combined with external teletherapy, were found to be with good condition. It is also found that their longevity is also increased[42]. Therefore by the calculation of absorbed dose at point A, point B, bladder reference point and rectum reference point in each case and by the verification of A point and B point dose with the suppliers stated value, we can achieve a good control of treatments in brachytherapy.

Chapter VIII
CONCLUSION

According to IAEA-TECDOC-1040, 1998, cancer of the cervix is the leading female cancer in developing countries, like Bangladesh. In our country 37% of all the female cancers is cervical cancer. Brachytherapy is an integral part of the treatment of cervix cancer. In primary stage the disease is curable only by brachytherapy. But as most of the patient of our country is first seen in relatively advanced stages of the disease so with brachytherapy, external beam therapy is also essential. In our study we calculated the absorbed dose at point 'A', point 'B', Bladder and Rectum for brachytherapy patients in Delta medical center Limited. Mirpur, Dhaka. From this thesis work it is found that the percentage variation at point 'A' and 'B' with the suppliers stated value was within the international standard. As there is no TPS (Treatment Planning System) in any radiotherapy department in our country, the process of radiation dose verification with suppliers stated value in case of brachytherapy treatment will ensure better patient management. This is the first type of work in our country. From the limited study in Delta Medical Centre Ltd., Mirpur, Dhaka, this study can be extended over other Brachytherapy facilities in the country. Further study should be necessary over external beam therapy also. There are few suggestions have given below for the consideration of the government.

- Government should install brachytherapy facility at least every medical college hospital so that the poor patients can have treatment at low cost.
- Every radiotherapy department should be equipped with (TPS), for better patient management.
- In case of low dose rate brachytherapy the manual afterloading should be replaced with remote afterloading for the radiation safety of the personnel involved.
- According to IAEA-TECDOC-1040, 1998, the medical physicist's responsibilities cover four major areas: dosimetry, radiation safety, quality control, and equipment selection and as a minimum each radiotherapy cetre shall have at least one medical physicist as a faculty member. So medical physicist post should be created for every radiotherapy department in our country.

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