LINAC-1

ADVANCES IN MEDICAL LINEAR ACCELERATOR TECHNOLOGY

HISTORY

Technological inventions and developments have created new possibilities and breakthroughs in medical era. The classic example is the discovery of X-rays by W.C. Roentgen, one hundred years ago. The first dawning rays appeared quite literally just before the beginning of the 20th century. In 1895 a German physicist named Wilhelm Conrad Roentgen accidentally discovered a form of radiation that could penetrate opaque objects and cast ghostly images on a photographic plate. Roentgen called his discovery X-radiation (the X was for "unknown"), and to prove its existence he took a picture of his wife's hand by exposing it to a beam of its rays. The result showed the bones of her hand and a ring on her finger as dark shadows on the photographic plate. It was the first x-ray image ever deliberately recorded.

The rays were soon identified as a form of electromagnetic radiation with wavelengths very much shorter than those of visible light. The shortness, or high frequency, of these wavelengths accounted for their penetrating power; their ability to delineate internal structure came from the fact that denser materials, such as bone, absorbed more of the rays. An American named William Coolidge soon put all this to practical effect with his 1913 invention of a vacuum tube that conveniently and relatively safely generated X rays. Medical doctors quickly seized on this wonderful new tool that enabled them to see, for example, how a bone was broken, or where a bullet might be lodged, or whether a lung harbored potentially lethal growths. A new field of diagnostic and later therapeutic medicine, radiology, was born. X rays also found their way out of the doctor's office and into the industrial world, where they were used to check for hidden cracks or other flaws in complex machinery and in structures such as bridges.

This technical innovation also paved the way for the field of radiotherapy to develop with the use of X Rays immensely. The technological advances that have taken place over the decades have led to the development of teletherapy machines with better radiation beam characteristics and greater accuracy.

Betatrons were first used as teletherapy machines in the early 1950's. They preceded the introduction of linear accelerators by few years. The major limitations of the betatron are its low x-ray dose rate, and limited field size. In addition, the machine size and complex mechanisms prevented betatron from becoming a major teletherapy machine.

External beam therapy can be broadly divided into kilovoltage therapy and megavoltage therapy depending upon the beam quality and their use. Kilovoltage ranges is further divided into contact therapy, superficial therapy and orthovoltage or deep therapy. All these are used according to the required depth dose profile.

X-ray beams of energy 1 MV or greater can be classified into megavoltage beams. Although the term strictly applies to x-ray beams, the gamma ray beams produced by the radionuclides are also included in this category if their energy is I MV or greater. Examples of clinical megavoltage machines are accelerators such as Van de Graff generator, Linear Accelerator, betatron, microtron and the telecobalt units. However the Linear Accelerator is the most commonly being used teletherapy machine.

WORKING AND DESCRIPTION OF VARIOUS COMPONENTS:

The Linear Accelerator is an accelerator designed to accelerate electrons to an energy of 4 MeV (and hence to serve as a 4-million-volt X-ray tube) though it must be stressed that the same principles apply to all versions of this machine. This is the simplest possible definition of Linear Accelerator to avoid vague generalizations. The basic principle involved is that radio-waves, like all other electromagnetic radiations, are alternating electric and magnetic fields traveling through space. Since an electric field applies a force to a charge particle placed in it, it follows that, if an electron is injected into a beam of radio-waves at an appropriate place and time, it will be acted upon by the force and tend to be carried along by the waves.

The basic design of a linear accelerator is hereby described. The radio-waves must have enough power to be able to 'carry' the electrons along. In practice it is not possible to provide this power continuously: it can only be generated in short bursts, or 'pulses', by a special thermionic valve called a magnetron. This was developed during the Second World War for radar work, and can produce several hundred pulses per second, each pulse lasting for a few microseconds (millionths of a second). Acceleration of the electrons to the required energy (4 MeV. in this case) takes place in what is called a corrugated wave-guide, which is a cylindrical tube across which are placed, at varying intervals along its length, metal disks with small central holes, which make them very similar to the iris diaphragm of a camera.

Although radio-waves, in common with all other electromagnetic radiations, travel with the same, constant, velocity in free space (i.e., with the 'speed of light'), they can travel more slowly in special circumstances, such as when passing along a wave-guide. In such circumstances the exact velocity depends on the spacing of the disks as well as the size of the holes in them. Thus, it is possible to arrange for the waves to be traveling at about zero to four times the velocity of light at the beginning of the guide but to have speeded up to about zero to ninety nine of that velocity by the time they reach the other end. Since the guide also directs the electric field of the waves along the axis of the tube, electrons can be carried along with the waves and, in a corrugated guide 1 meter long, will acquire the same energy as they would have acquired had a potential difference of 4 million volts been applied across the tube.

As the pulses start down this guide electrons are shot into them from a heated filament, which is at a negative potential of 40 kV. The electrons have the same speed as the waves and are carried along, accelerating with the waves, to the end of the guide and on to the target where 4-MV. X-rays are generated. The precise energy acquired depends on the details of the wave-guide design and especially upon its length—the longer the guide the greater the energy acquired.

From the end of the wave-guide the electrons travel a short distance to the thin target, which closes the end of the vacuum vessel which encloses the corrugated wave-guide.

(Like every X-ray tube, and for the same reasons, the linear accelerator's acceleration section is highly evacuated.) The target is made of a tungsten-copper alloy (which has good thermal conductivity as well as high atomic number) and is about 1 mm. thick. A 'transmission target' is used in most of the X-rays generated traveling in a forward direction.

In the 4-MV Linear Accelerator water flowing through a small pipe fastened round the periphery of the target disk is sufficient to carry away any heat generated. Another advantage of the high efficiency of X-ray production is that a small focal spot may be used without danger of overheating and melting the target centre. A 6-mm. diameter spot is quite usual and therefore no great geometric penumbra results even when the beam-defining diaphragms are at some distance from the patient.

Successful generation of high-energy radiation does not, in itself, guarantee successful therapeutic application, the mounting of the X-ray tube being, in some ways, almost as important as the tube itself. One of the reasons why linear accelerators have proved so good is the excellence, for radiotherapy, of their 'isocentric' mounting.

As already stated, the corrugated wave-guide is 1 meter long and the cylinder which houses that guide, the electron gun, the collimators, and other auxiliary gear is 180 cm. long. This length means that the tube cannot readily be rotated to point in all directions. The machine can be rotated, about the horizontal axis, from pointing vertically downwards, to a position in which the beam points upwards to an angle of 20° to the horizontal. Any further rotation would cause the apparatus to strike the floor, unless a special retractable floor, or a pit, is provided. Complete rotation is impracticable in a machine of this size.

DEVELOPMENTS:

The developments made in the field of radiotherapy accounts for the increase of therapeutic ratio. Many new versatile machines and techniques have developed for the best optimum care of the patient. Historically, the maximum radiation dose that could be given to a tumor site has been restricted by the tolerance and sensitivity of the surrounding nearby healthy tissues. This is the reason why there has been a radical change made in the linear accelerator technology to make the treatment delivery more precise. The era has witnessed the change from conventional radiation with the linear accelerator to the conformal therapy practiced with the linear accelerator. The advances have been summarized as follows:

3DCRT (Three Dimensional Conformal Radiation Therapy)

Several technologic developments have combined to move radiation oncology into a new era, now referred to as the three-dimensional (3D) radiation therapy or 3D conformal radiation therapy (3DCRT) era. Modern imaging technologies, including x-ray computed tomography (CT) and magnetic resonance imaging (MRI) provide a fully 3D model of the anatomy of the patient with cancer that allows radiation oncologists to identify more accurately tumor volumes and their relationship with other critical normal organs. Powerful x-ray CT simulation and 3D radiation therapy treatment planning (3DRTP) systems have been commercially available for over a decade and are rapidly replacing the conventional radiation therapy x-ray simulator and two-dimensional (2D) dose planning process in many clinics . In addition, the latest-generation medical linear accelerators have sophisticated computer-controlled multileaf collimator (MLC) systems that provide aperture and beam-intensity modulation features capable of precise shaping of dose distributions.

Three-dimensional CRT plans usually use an increased number of radiation beams that are shaped using beams-eye-view (BEV) planning to conform to the target volume. To improve the conformality of the dose distribution, conventional beam modifiers (e.g., wedges or compensating filters) are sometimes used. This form of 3DCRT must now be referred to as traditional 3DCRT or conventional 3DCRTto avoid confusion with a newer, more advanced form of conformal therapy, called intensity-modulated radiation therapy (IMRT).

Three-dimensional treatment planning is not just an add-on to the well established 2D radiation treatment planning process. Rather, it represents a radical change in practice, particularly for the radiation oncologist. The 2D treatment planning approach emphasizes the use of a conventional x-ray simulator for designing beam portals based on standardized beam arrangement techniques and bony landmarks visualized on planar radiographs. In contrast, 3D treatment planning emphasizes an image-based virtual simulation approach for defining tumor and critical structure volumes for the individual patient.

However, it should be understood that a critical question in treatment planning is how well the tumor volume(s) and normal tissue volumes can be defined for each patient. The new 3D planning process does put new demands on the radiation oncologist to specify target volumes and critical structures with far greater accuracy than before. In addition, the 3D approach does not necessarily result in smaller treatment volumes for all sites. Moreover, this new technology also places new demands on the radiation oncology physicist to ensure adequate quality assurance (QA) measures are in place to accommodate the new 3DCRT process (e.g., the need for new precision in tumor imaging, patient setup reproducibility, organ motion assessment, and treatment delivery verification).

The use of the terms 2D and 3D as descriptors for the planning process continues to cause some confusion in the radiation oncology community. Planning the treatment of the patient with cancer is (and always has been) a 3D problem (at least in regard to the spatial distribution of dose), and when we refer to 2D planning, we really are referring to the process and tools used. Also, 3DRTP does not require the use of "noncoplanar" beams, a common misconception. In fact, the overwhelming majority of the thousand plus cases that were entered into the Radiation Therapy Oncology Group (RTOG) 94-06 prostate 3DCRT protocol used coplanar beam arrangements. Radiation oncologists will be able to transition to 3D planning much more easily if they approach 3DRTP as a new treatment planning process, rather than emphasizing a particular beam configuration, or considering it simply the purchase of new planning equipment.

Patients should be aware of marketing efforts by manufacturers and hospitals that imply one linac technology is an improvement over another, either by the way it delivers radiation or by the way it images tissues. The biological effect and probable outcome will be the same regardless of whether a gantry or robot is used for delivery. Conformal radiation treatments have the ability to deliver a higher radiation dose within the tumor, thus causing more damage to the tumor and less damage to surrounding healthy tissues than conventional external beam radiation treatments.

IMRT (Intensity Modulated Radiation Therapy)

IMRT is short for Intensity Modulated Radiation Therapy. The intensity of the radiation in IMRT can be changed during treatment to spare more adjoining normal tissue than is spared during conventional radiation therapy. Because of this an increased dose of radiation can be delivered to the tumor using IMRT. Intensity modulated radiation therapy is a type of conformal radiation, which shapes radiation beams to closely approximate the shape of the tumor. It is a state-of-the-art cancer treatment method that delivers high doses of radiation directly to cancer cells in a very targeted way, much more precisely than is possible with conventional radiotherapy. IMRT can deliver higher radiation doses directly to cancer cells while sparing more of the surrounding healthy tissue. This has important advantages in oral cancers as it allow the beams to hit their target area while missing the surrounding structures such as the salivary glands.

IMRT enables a more precise conformal radiation dose distribution to the target area by allowing the physician to control the intensity of the radiation beam within a given area. Again, this means a much higher dose of radiation may be given to a tumor without an increase in radiation delivered to the normal tissue. IMRT utilizes beams or multileaf collimators that can turn on or off or be blocked during treatment, varying the radiation beam intensity across the targeted field.

The radiation beams may be moved dozens or hundreds of times and each may have a different intensity, resulting in radiation sculpted in three dimensions. The healthy surrounding tissue receives a smaller dose of radiation than the tumor does. Treatment planning for IMRT and other conformal radiation is more complex than for conventional radiation therapy, taking an average of 2–3 days for each patient. Three-dimensional planning for conformal radiation versus simple one-slice planning for conventional radiation therapy extends treatment planning time for the patient.

The patient will be fitted with a reusable localization device, which may be a mask, body frame or other device. These devices assist the radiation delivery machines in targeting with more accuracy. Frequently, the localization device is molded to fit the precise contours of the individual patient. Alternatively, a body frame may be used. The molded device or body frame will be placed on the patient each time he receives a treatment. Multiple treatments are usually required with conformal radiation, the same as with conventional radiation therapy. The number of treatments may range from 1–28, which is less than with most conventional radiation treatments. Actual treatment time for each session is typically longer than with conventional radiation therapy because of the complexity of the treatment itself.

Radiation treatments given daily or multiple times a day are called fractionated treatments. As with conventional radiation treatments, by giving the treatments in a fractionated manner, the normal healthy tissue that does receive minor radiation overlap is thought to be able to regenerate itself faster than the tumor can, and therefore be less damaged. Additionally, radiation given in fractions is able to reach the tumor cells during different stages of cell growth, possibly causing more damage.

The side effects of IMRT are the same as those of conventional radiation therapy but tend to occur less frequently and with less intensity in the short and long term. IMRT and conformal radiation therapy are deliverable anywhere within the body, as long as the affected area is properly immobilized. As with conventional radiation therapy, there is no limit to the size of tumor that can be treated. Patients who have previously received the maximum amount of radiation deliverable by conventional radiation therapy are able to be treated with IMRT and other conformal radiation therapy.

The areas most commonly treated with IMRT are: prostate, spine, lung, breast, kidney, pancreas, liver, larynx, tongue and sinus. The brain is treated with IMRT when one-session radiosurgery is not appropriate or unavailable.

As with conventional radiation therapy, treatment with IMRT or other conformal radiation always involves a radiation oncologist and physicist. Should the treatment site be within the brain, a neurosurgeon is required to be a part of the team and the patient should insist upon it.

As previously stated, before the advent of conformal radiation therapy the maximum radiation dosage was restricted by the impact it would have on nearby tissues. For instance, when conventional radiation therapy is utilized to treat lung or breast cancer, some overlap of radiation may occur to the arteries of the heart. In some instances, this can cause these arteries to thicken over time, restricting blood flow. This may or may not be a problem, depending on the blood flow within the other heart arteries and the patient's overall health. For a few patients, this may necessitate a bypass operation in the future. With conformal radiation therapy and IMRT for the lung or breast tumor, the radiation overlap to the heart arteries is shown to be minimal or nonexistent, possibly eliminating the need for further invasive care and/or heart problems.

IMRT uses computer-generated images to plan, and then deliver tightly focused radiation beams to cancerous tumors. Clinicians use it to exquisitely "paint" the tumor with a precise radiation beam that conforms as closely as possible to the shape of the tumor.

IMRT can be used to treat tumors that might have been considered untreatable in the past due to close proximity of vital organs and structures. Treating such tumors requires tremendous accuracy. For example, in the case of head and neck tumors, IMRT allows radiation to be delivered in a way that minimizes exposure of the spinal cord, optic nerve, salivary glands or other important structures. In the case of prostate cancer, exposure of the nearby bladder or rectum can be minimized. IMRT is being used to treat tumors in the brain, breast, head and neck, liver, lung, nasopharynx, pancreas, prostate, and uterus.

A powerful computer program optimizes a treatment plan based on a physician's dose instructions, and information about tumor size, shape and location in the body. A medical linear accelerator, equipped with a special device called a multileaf collimator that shapes the radiation beam, delivers the radiation in accordance with the treatment plan.

The equipment can be rotated around the patient to send radiation beams from the most favorable angles for giving the tumor a high dose while preserving important healthy tissues. Look at these images of multiple angle beams, and compare them in your mind to the conventional 3-beam approach (left, right, and front). Obviously when the tumor is very localized, this method of treatment has distinct advantages.

TOMOTHERAPY

Tomotherapy is actually a form of intensity modulated radiation therapy (IMRT). tomotherapy is more advanced and versatile than other forms of IMRT. Quite simply, tomotherapy represents the future of radiation therapy. The leap in technology from regular radiation therapy is overwhelming. Hi-Art Tomotherapy shares a lot of technology with CT scanners, otherwise known as computerized tomography. The machine even looks like a CT scanner. Some of its amazing capabilities are:

- Tomotherapy will do a quick CT scan before each treatment starts, to ensure the patient is aligned perfectly.

- A thin beam is rotated around the body, entering from many directions, while the couch simultaneously moves into the machine. This effectively results in thousands of little beamlets of different intensities entering the body, converging on the tumors.

- A very powerful multiple-processor computer calculates the treatment plans and coordinates treatment delivery.

- Tomo can treat big or little tumors, single or multiple tumors, one region of the body or several regions, to the same dosage in every area or to multiple different dosages. The possibilities are endless!

- Tomo can avoid organs we tell it to. We can miss the salivary glands and treat the throat tumor. Miss the spinal cord and retreat the spinal bone. Miss the kidneys and treat the pancreas.

tomotherapy has been particularly valuable for the following conditions:

- Retreating previously irradiated areas of the body

- Treating multiple metastases simultaneously

- Treating all metastases throughout the body simultaneously

- Treating lung cancers, breast cancers, and prostate cancers.

The main clinical implications are as follows:

Retreatment: Many radiation oncologists are reluctanct to give repeat radiation to the same part of the body that has already received radiation in the past. It can be dangerous to re-irradiate, because you could risk complications such as excessive scarring, ulceration, or pain. However, tomotherapy is a natural choice for retreating tumors that have already been irradiated. Because tomotherapy is so targeted, it can be safer to re-irradiate, because the surrounding healthy tissues will receive less radiation dose.

Prostate cancer: Prostate cancer is treated extremely well with tomotherapy. Many men have heard about using IMRT (intensity modulated radiation therapy) for prostate cancer, and tomotherapy is a very advanced form of IMRT.

Multiple Metastases: With standard radiation therapy, often a different radiation therapy plan has to be created for each separate tumor treated. With tomotherapy, it is easy to treat multiple tumor simultaneously, whether they be in the brain, liver, lungs, bones, or in several organs.

Total Metastases Irradiation (TMetI): TMetI describes the targeted and simultaneous radiation treatment of multiple tumors throughout the body.

Brain Tumors: Tomotherapy can be used instead of gamma-knife, cyberknife, or stereotactic radiosurgery to treat brain tumors. Tomotherapy is definitely more flexible than these therapies in that it can treat multiple tumors at the same time, can treat large or complex shaped tumors, and can be easily divided up into a series of daily treatments. Tomotherapy can do a technologically marvellous job treating glioblastoma multiforme.

Lung cancers: This is a very advanced way to treat lung cancer. We have not yet statistically analyzed our results, but the physicians at our center have been impressed by the tumor response rates and an apparent reduction in the amount of radiation lung injuries.

Carcinoma of Breast: After a lumpectomy (partial mastectomy), radiation therapy is usually given to the breast, to eliminate any cancer cells that may still be present. For early stage cancers, we often use breast brachytherapy, which takes only 5 days, and treats only a portion of the breast. For more advanced breast cancers, or for women who do not want brachytherapy, we use external beam irradiation. The standard method has been to use two beams, aimed at the breast from each side. This can result in a lot of unwanted collateral radiation. When tomotherapy is used, we are able to contour the high dose region much more precisely to the breast tissue. The high dosages can be kept off the lungs and heart. If lymph nodes such as the internal mammary nodes are also being included in the treatment, tomotherapy can result in an even more dramatic reduction in unwanted radiation. With tomotherapy we can also give a higher dose each day to the area of the breast where the tumor used to be. This can shorten the length of radiation therapy from 7 weeks down to 5 weeks.

Head and Neck Cancers: IMRT is revolutionizing the way that head and neck cancers are irradiated. With cancers of the tongue, throat, and larynx, often all the lymph glands of the neck have to be radiated along with the primary tumor. This usually results in permanent damage to the salivary glands, and a life-long dry mouth, also known as xerostomia. With IMRT, it became possible to treat the neck lymph nodes and avoid the salivary glands. Tomotherapy, which is a special form of IMRT, has perfected this technique and reduced the parotid dose even further compared with normal IMRT.

IGRT (Image Guided Radiation Therapy)

It is a one step progress been made after IMRT. Traditionally, imaging technology has been used to produce three-dimensional scans of the patient’s anatomy to identify the exact location of the cancer tumor prior to treatment. However, difficulty arises when trying to administer the radiation, since cancer tumors are constantly moving within the body (for example, from movement caused by breathing). Hence, the exact location of the tumor may have changed between the time of scan and actual treatment. IGRT combines a new form of scanning technology, which allows planar or X-ray Volume Imaging (XVI), with IMRT. This enables physicians to adjust the radiation beam based on the position of the target tumor and critical organs, while the patient is in the treatment position. The first use of this technology took place at the Netherlands Cancer Institute during July 2003.

STEREOTACTIC IRRADIATION:

Stereotactic irradiation is the delivery of highly conformal radiation to a stereotactically defined target volume, which results in a rapid dose fall-off at the field edges. The two main types of stereotactic irradiation are stereotactic interstitial irradiation and stereotactic external-beam irradiation. Stereotactic interstitial irradiation consists of either implantation of temporary or permanent radioactive sources or application of electrons or low-energy photons to the target intraoperatively. Stereotactic external-beam irradiation, however, is a noninvasive treatment. When the total radiation dose is delivered in a single session, it is termed stereo-tactic radiosurgery (SRS). When the total dose is delivered in more than one fraction, it is known as fractionated stereotactic radiotherapy (SRT). Stereotactic irradiation has a very important role in the treatment of both benign and malignant brain tumors. SRS allows the delivery of a biologically high radiation dose in an effort to maximize local control of malignant tumors or to achieve obliteration of arteriovenous malformation (AVM) lesions. In contrast, the use of fractionated SRT permits a high degree of conformality to benign tumors with minimum acute and long-term toxicities.

Since treatment of the first patient by Leksell in 1951, tremendous progress has been made in the field of stereotactic irradiation. The important advancements include gamma knife radiosurgery, charged-particle radiosurgery, linear accelerator-based (linac) stereotactic radiosurgery and radiotherapy, intensity-modulated radiosurgery (IMRS) and radiotherapy (IMRT), and extracranial radiosurgery. Advances in neuroimaging and dose-planning software have helped to delineate the target and minimize the dose to normal tissues. Treatment outcome and toxicity data have helped to define the doses used in radiosurgery and to establish the important role of fractionated stereotactic irradiation.

General goals of stereotactic irradiation, regardless of the radiation modalities used, include: (a) rapid dose fall-off outside the target volume, (b) conformaliry of prescribed dose to the target volume, and (c) impeccable repositioning accuracy. To achieve these goals, multiple convergent noncoplanar beams are used to deliver radiation to a precisely defined target. Stereotactic immobilization must be used to allow treatment reproducibil-ity, repositioning, and the use of a minimal margin around the target.

Regardless of the type of stereotactic irradiation technique used, the following apply. First, the volume of nontarget tissue that receives a significant dose is strongly dependent on the size of the target and the conformity of the isodose to the target. As the volume of the target increases, the volume of the nontarget tissue that receives a significant radiation dose increases. Second, the use of multiple isocenters can increase conformality but at the expense of dose homogeneity within the target. Third, the importance of dose fractionation in conventional irradiation also applies to stereotactic irradiation.

Stereotactic Radiosurgery: SRS is the stereotactically directed, highly focal delivery of large single radiation doses. SRS can be applied as interstitial brachytherapy or intraoperative radiotherapy using electrons or low-energy X-rays. Other modes of SRS delivery include external stereotactic irradiation using the gamma knife, charged particles, modified linear accelerators, or the miniature linear accelerator with a robotic arm (such as Cyberknife) . These methods have been used for AVMs, small benign tumors and malignant lesions, and clinical situations in which high biologic doses are required to eradicate or effectively treat these lesions. SRS should be limited to lesions measuring up to 3 cm in diameter. There has been a decrease in the use of SRS in the treatment of benign tumors because of the recognition that previously used high doses have resulted in unexpectedly high acute and long-term toxicities and that high biologic doses are not necessary to control these lesions. The availability of alternative stereotactic techniques using fractionated irradiation also is a factor.

Stereotactic Radiotherapy: Experiences with fractionated radiotherapy in the treatment of benign and malignant diseases have defined the importance of fractionation in decreasing acute and late radiation toxicities. Tissue volumes targeted with stereotactic irradiation, irrespective of the degree of conformality, always include in the high-dose regions normal tissues or critical organs that potentially can cause morbidity. The understanding of the importance of fractionation and the limitation of radiosurgery has led to the development of SRT, which is the delivery of stereotactically directed and highly focal conventionally fractionated irradiation (1.8 to 2.0 Gy per day for a full course of 5 to 6 weeks). SRT provides the same precision in target localization, patient immobilization, and focal dose distributions as that obtained with SRS. SRT combines the precision of stereotactic positioning with the radiologic biologic advantage of fractionation. The linac-based system, charged particles, and Cyberknife all have the capability to perform SRT. Relocatable noninvasive stereo-tactic head rings are used for daily treatments. SRT is not feasible with gamma knife because of the impracticality of daily insertion of an invasive head ring and the limitation of small field sizes. SRT mainly is indicated in the treatment of benign brain tumors.

Hypofractionated Stereotactic Radiotherapy: Whereas SRT uses conventionally fractionated daily irradiation of 1.8 to 2.0 Gy for a 5- to 6-week radiotherapy course, hypofrac-tionated stereotactic radiotherapy (H-SRT) delivers the total dose using a hypofractionated radiotherapy schedule. Various fractionation schedules currently are used and include, among others, 25 Gy in five consecutive daily fractions, 20 Gy in weekly doses of 4 to 5 Gy, and 24 Gy given in three 8-Gy fractions in 1 day. The rationale for the different fractionation schedules used is based on biomathematical models. Because the comparison and quantification of the biologic effectiveness of these different fractionation schedules are not feasible, one must rely on clinical data to support the use of H-SRT. Because of the limited clinical experience with H-SRT, this form of SRT in the treatment of benign tumors and inoperable arteriovenous malformations has to be considered investigational at this time. For malignant tumors that are too large for SRS boosts, the use of H-SRT promises palliation of symptoms while limiting acute toxicities.

CYBERKNIFE

The CyberKnife was invented at Stanford by John Adler, MD, and is considered a major advance in the radiological treatment of cancer. It integrates a robotically-controlled mobile linear accelerator with a state-of-the-art image-guidance system, with a few new features:

The improved power of the machine shortens treatment times for body tumors.

It allows us to treat very young children under anesthesia, a treatment that was previously unavailable to us.

The positioning of the imaging devices increases the maneuverability of the robot.

This will potentially allow us to expand treatment to tumor sites that are not currently treated with existing platform.

As a radiosurgery tool capable of delivering highly precise, high dose radiation without cumbersome and painful stereotactic frames, the CyberKnife extends the use of radiosurgery beyond brain tumors into various regions of the body including the spine, lung, thorax, abdomen and pelvis. The original CyberKnife was developed at Stanford, where the first patient was treated in 1994. The prototype unit was used between 1994 and 2001. The CyberKnife was approved by the FDA (U.S. Food and Drug Administration) in 2001, and the first FDA approved CyberKnife was installed at Stanford in October, 2001.

FUTURE PERSPECTIVES:

The global burden of cancer is increasing very rapidly in developing countries. According to WHO projections, by the year 2015 there will be 15 million new cancer patients in the world each year, out of which 10 million will be in the developing countries. Ensuring that these patients receive appropriate treatment is a major challenge. The business of radiation oncology has certainly changed, moving from obscure basement cobalt rooms to fancy offices overflowing with expensive equipments. Perhaps the apple doesn’t fall far from the tree. The technology for delivering radiation has improved and with it an improvement in the therapeutic ratio. The field of radiation oncology has witnessed tremendous developments in order to increase the therapeutic ratio and to give best possible care to the patient. Still the field of radiation oncology will witness further such developments to treat the patient in the very best possible way.