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# Breakthrough in cancer therapy

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CANCER is one of the most dreaded diseases and also a major killer not only in our country but also worldwide. Normal cells multiply by cell division, but there is a regulatory mechanism which limits the process. In cancerous cells this regulatory mechanism breaks down, thus leading to uncontrolled growth. The regulatory mechanism is not fully understood, but seems to be related to ionic currents set up when cells touch each other. In cancerous cells these currents are inhibited.

The ICMR estimates that over 5 million cases of cancer existed in 1990, and that 1.5 million new cases occur every year. These figures are expected to increase three-fold in the last decade of this century. In the second half of this century there has been tremendous progress in cancer therapy and management worldwide. In the western countries, emphasis is put on early detection of cancer cases and early treatment. This has led to a great increase in the survival rates. Another factor contributing to the increase in survival rates in these countries is the progress in therapy methods. The three common modes of treatment are chemotherapy, surgery and radiotherapy respectively. Steady progress is continuing in all these fields, leading to a steady improvement in prognosis for the patients. New modes of treatment are also being investigated, including photodynamic therapy (sensitising cancer cells with a dye which is preferentially absorbed in the cancer site and destroying them by shining strong light on them) and hyperthermia (application of heat to cancer sites. This mode is particularly beneficial in conjunction with other treatment modes like radiotherapy). Unfortunately, in our country early detection of cancer has not yet become common in spite of the best efforts of the doctors. This is all the more tragic in that over two-thirds of the reported cases in our country are cancers of the head and neck, Oesophagus, Cervix and Breast. These cancers are relatively easy to detect, and respond well to early treatment. In this article, we will look at the role of linear accelerators in radiotherapy.

In radiotherapy ionising radiation (mainly X-rays and electrons, though heavier particles like protons, pions and neutrons are also being experimented with) is used to destroy the cancer cells. When the ionising radiation interacts with matter it knocks off millions of electrons from the atoms in its path. These electrons damage the DNA in the cell nuclei. In common with other established therapy modes, radiotherapy also shares the disadvantage of destroying normal tissue along with the diseased tissue. Thus, one of the main challenges of the treatment mode is to minimise damage to ordinary cells while destroying all the cancer cells. This is why protons, pions and neutrons are being experimented with, in spite of the much higher cost of producing these particles with the required energies. These particles deposit the maximum amount of energy at a specific depth within the body (the depth depends on their initial energy). Thus, by tuning the energy one can ensure that the damage is maximised in the region of the cancer site. However, in routine treatment one normally uses X-rays or electrons, since these are relatively cheaper and easier to produce.

The most common sources of radiation are radioisotopes like Cobalt, or electron linear accelerators. Some units use microtrons, in which the electron acceleration is done by microwave cavities as in a linear accelerator, but the beam is made to bend back and pass through the cavities several times. In radiotherapy units the patient is placed on a couch, and the sources are mounted in such a way that they can be rotated around the patient, with the cancer site being always on the axis of rotation (isocentric mounting). Thus, by giving the radiation dose from different directions one can minimise the damage to ordinary cells while delivering the maximum dose to the cancer site. In the advanced countries the emphasis is now on using electron linear accelerators, since these give higher energies than radioisotopes, and also give a sharper beam (smaller penumbra). Thus, linear accelerators are better than radioisotopes in concentrating the damage at the cancer site.

They also can be switched off when not required, thus avoiding radiation safety problems when not in use. Due to the natural process of radioactive decay, the dose delivered by radioisotopes reduces over the course of years, and after a few years the source has to be replaced. The spent radioisotopes still emit dangerous radiation, and their safe disposal is a problem. Radioisotope sources are however cheaper and there is less of sophisticated equipment to maintain.

In the electron linear accelerator electrons generated from a thermally heated cathode are preaccelerated to a few Kilovolts by an electron gun and then fed into a stack of microwave cavities. Electromagnetic energy in the microwave range (in this particular application, at a frequency of about three billion Hertz or cycles per second) is fed to the linear accelerator stack, and sets up large Electric fields of the order of several million Volts per metre in the stack. These fields capture a portion of the input electron beam and accelerate it to energies equivalent to falling through a voltage drop of 4 to 40 Million volts (depending on the machine). The acceleration of electrons in the stack is a resonant phenomenon, analogous to the case where several small pushes to a child's swing delivered at the proper moments sets it into large amplitude oscillations. The current delivered by the electron beam is of the order of tens of milliamps. The beam is not on all the time. The power is supplied in pulses of about four millionths of a second, with about two hundred and fifty pulses per second. Thus, while the peak power required by the machine is in millions of Watts, the average power is only a few Kilowatts. In most cases the accelerated electrons are made to impinge on some target like Tungsten, thus producing X-Rays. In some cases involving tumors on the surface the electrons may be used directly. In modern machines one can switch from electron mode to X-Ray mode and vice versa (except in case of lower energy machines).

Prior to 1957 our country had only kilovolt radiotherapy machines. In 1957 the first radioisotope unit (using Cobalt) was installed in Madras. Today, we have about a hundred radiotherapy centres, mostly using Cobalt radioisotope units. There are a handful of Caesium radioisotope machines and about ten linear accelerator units. The total comes to a woefully inadequate figure of about one hundred and sixty units. There are also regional imbalances in the distribution of these units. The WHO recommends that there should be at least one radiotherapy unit for every million population. Thus, we will need over a thousand new units by the end of this decade. Many of these new units will have to be based on the linear accelerator. Over two-thirds of all cancer cases need radiotherapy, either as the primary mode of treatment (about half the cases), or in conjunction with other modes like chemotherapy and surgery, or as a palliative to ease the pain in incurable cases.

In our country the knowhow for indigenous manufacture of linear accelerators delivering four Megavolts X-Rays has been developed in a collaborative project funded by the Department of Electronics and executed by the Society for Applied Microwave Electronics Engineering Research (SAMEER), Bombay, Central Scientific Instruments Organisation (CSIO), Chandigarh, and Post-Graduate Institute for Medical Education and Research (PGIMER), Chandigarh.

At the international level new developments have occurred on many fronts. Linear Accelerator systems with an option to switch between two X-Ray energies and three or four electron energies have been developed. There is now greater flexibility in defining the treatment beam shape and size, with independently movable beam collimator jaws. New imaging techniques like CT and MRI scans have led to increased precision in location of tumors. Advances in computers have made possible interactive graphic displays and more accurate calculations of the dose distributions within the human body. Advances in the interfacing of computers with equipment will lead to greater integration of the image scanning, treatment planning and dose delivery stages. Greater flexibility in the choice of the system parameters will lead to further improvement of the dose concentration to the cancer affected region while reducing the dose delivered to sensitive organs. If the patient's treatment plan and records are available to the computer which controls the linac system, then it can verify that the system settings match with the requirements. Thus, set-up errors can be minimised. The technologist and therapist are also saved some of the bother of record maintenance, which can be taken over partly by the computer itself.

In conclusion, while we have not found the final cure for cancer, much progress has been made in the treatment of cases, especially when they are detected early. Radiotherapy plays an important role in cancer treatment. Electron linear accelerators are important for radiotherapy. In our country as well as internationally, great progress is being made in the technological and medical aspects of cancer radiotherapy using linear accelerators.