Therapy

As life expectancy steadily improves, the incidence of cancer also increases as the population ages. Up to 50% of cancer patients undergo radiotherapy - a form of protracted biological surgery by selective sterilization of malignant cells.

X-ray radiotherapy

The most common form of radio therapy is X-ray therapy, where a beam of photons or their parent electrons break down hydrogen bonds within the body's cells and remove certain DNA information necessary for cell multiplication. This process can eradicate malignant cells leading to complete recovery, to the remission of some cancers, or at least to a degree of pain relief.

The radiotherapy instrument is usually an electron linac, and the electrons are used either directly in 'electrotherapy' for some 10% of patients, or the electrons bombard a conversion target creating a broad beam of high energy photons or 'penetration X-rays'.

The simplest machine consists of several accelerating sections at around 3 GHz, accelerating electrons to 6 MeV; a cooled tungsten target is used to produce a 4 Gray/min X-ray field which can be collimated into a rectangular shape at the patient position. This tiny linac is mounted inside a rotating isocentric gantry above the patient who must remain perfectly still. Several convergent beams can also be used to increase the delivered dose.

More sophisticated accelerators operate at up to 18 MeV to increase penetration depths and decrease skin exposure. Alternatively, electrotherapy can be used with different energies for lower and variable penetration depths - approximately 0.5 cm per MeV. In this way surface tissue may be treated without affecting deeper and more critical anatomical regions.

This type of linac, 1 to 2 metres long, is mounted parallel to the patient with a bending magnet to direct the beam to the radiotherapy system, which includes the target, thick movable collimator jaws, a beam field equalizer, dose rate and optical field simulation and energy controls.

There are over 2000 accelerator-based X-ray treatment units worldwide. Western countries have up to two units per million population, whereas in developing countries such as Bangladesh, the density is only one per 100 million.

Several major medical equipment companies manufacture X-ray therapy systems - General Electric, Mitsubishi, Philips, Siemens and Varian. In this crowded marketplace where the useful lifespan of machines exceeds 10 years, purchase prices are less than $1 million per unit.

X-ray therapy remains the most common and cheapest form of accelerator therapy. Ongoing technical developments aim to achieve better matching of dose delivery to tumour volume; multileaf collimators shape the X-ray field to the biomedical target, and portal imaging from behind the patient can control positioning and dose delivery.

Combined compact X-ray sources are being developed with both treatment and realtime dosimetry control, incorporating CT scanning into one single device. Integrated diagnosis and therapy is the direction for R&D investment, and this should lead to smaller hospital space requirements, lower operating costs, and elimination of external data handling, resulting in simpler and more cost effective clinical procedures.

From D Tronc, General Electric Medical Systems, Paris

Neutron therapy

Standard radiotherapy uses X-rays or electrons which have low LET (linear energy transfer); in contrast, particles such as neutrons with high LET have different radiobiological responses. In the late 1960s, clinical trials by Mary Catterall at the Hammersmith Hospital in London indicated that fast neutron radiation had clinical advantages for certain malignant tumours.

Following these early clinical trials, several cyclotron facilities were built in the 1980s for fast neutron therapy, for example at the University of Washington, Seattle, and at UCLA. Most of these newer machines use extracted cyclotron proton beams in the range 42 to 66 MeV with beam intensities of 15 to 60 microamps. The proton beams are transported to dedicated therapy rooms, where neutrons are produced from beryllium targets.

Second-generation clinical trials showed that accurate neutron beam delivery to the tumour site is more critical than for photon therapy.
In order to achieve precise beam geometries, the extracted proton beams have to be transported through a gantry which can rotate around the patient and deliver beams from any angle; also the neutron beam outline ("field shape") must be