Star Wars killer beam takes on cancer cells

RADIOTHERAPY

Proton radiation, originally developed as a Star Wars space weapon, is being adapted to kill tumours. Experts say that it is more accurate and has fewer side effects than x-rays or neutron therapy. JANE BIRD reports

A DEADLY radiation technology developed for Star Wars could provide the most promising treatment yet for cancer by killing tumorous cells.

The technique is being developed at AEA Technology, the newly commercialised arm of the UK Atomic Energy Authority. Originally it was to be used in President Ronald Reagan's Strategic Defence Initiative as a powerful beam to knock out enemy satellites in space.

Now proton therapy, using the positively charged particles in an atom's nucleus, is being adapted for use in hospitals where it could provide significant improvements in radiotherapy.

The results so far look very promising. A cyclotron at Harvard has treated several hundred rare tumours that occur near the brain and spinal cord. It has had a 75% success rate, compared with 30% using x-rays. Data from elsewhere on using protons for eye cancer show a 97% success rate.

Neil Griffiths, medical applications manager at AEA Technology, says: "Protons combine several of the advantages of the conventional treatments with neutrons and x-rays, without the disadvantages."

In the treatment, protons are fired down a pipe where they pick up energy as they are accelerated by surrounding electric fields. When they are at their optimum energy level they are diverted out of the pipe and directed into the patient's tumour.

Beams of radiation have been used for many years to destroy cancerous tumours where surgery was impossible, either because the patient was too old or because the cancer was inaccessible.

The radiation causes ionisation – an effect where electrons are knocked off atoms throughout a cell until its chemical structure is destroyed. The molecules of DNA, which determine the growth of a cell, are broken up so that they can no longer reproduce.

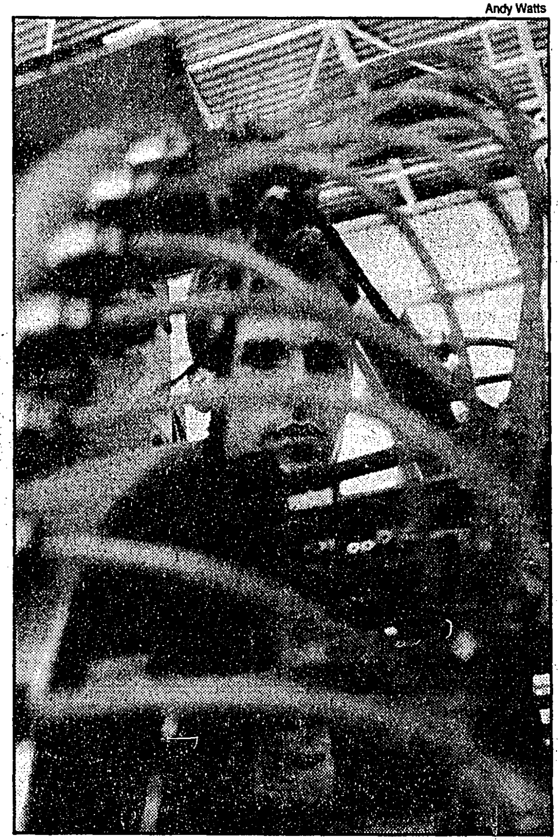
The most popular radiation treatment uses x-rays. But the problem is that the edges of the beam tend to be fuzzy so that treatment always ends up dosing quite a lot of the area around the tumour. This is a severe drawback, especially if the tumour is in a region close to the brain or spinal cord.

Another problem is that an x-ray beam loses energy progressively as it passes through the body, so the maximum dose is at the surface and not at the tumour.

One solution is to fire beams from three different positions so that the highest dose is delivered at the intersection point – the tumour. But side effects can still be unpleasant.

In the past two decades much enthusiasm has centred on an alternative – neutron therapy (neutrons are the electrically neutral components of an atom). It was thought that neutrons would be more effective on tumour tissue than on healthy tissue.

Andy Watts



● Proton type: Griffiths with sub-atomic particle creator

In Britain, cyclotrons to deliver low-energy neutron beams were set up in Edinburgh, Clatterbridge near Liverpool, and Hammersmith Hospital in London. But the results never lived up to expectations, and there have been some cases where the healthy tissue has been damaged more than the tumour. Last month The Sunday Times revealed that more than 30 patients in Britain have died as a result of neutron therapy.

Contrary to the situation with x-rays, the proton beam has a very sharp edge. It travels in very straight lines, can be programmed to stop abruptly at a specific point, and delivers almost all its ionising effect at that point. This means that organs beyond the tumour receive virtually no radiation.

"It reduces the likelihood of side effects, and allows a higher dose of radiation to be given to the cancer. In many cases it could increase the chances of successful treatment," says Griffiths.

Another advantage of protons over x-rays or neutrons is that their electrical charge allows them to be steered by magnetic fields, making them much more precise.

The benefits of protons have been known since the 1940s, but they have not been developed because of the expensive machinery needed to create them. Until now the only proton-beam accelerators have been unsuitable cyclotron machines built about 40 years ago for high-energy physics and adapted for medical use after they had been superseded by more advanced technology in physics.

They are generally some distance from hospitals and the patient often has to be treated in awkward positions because their proton beams are inflexible. Even with protons, there is some dose delivered to the healthy tissue so

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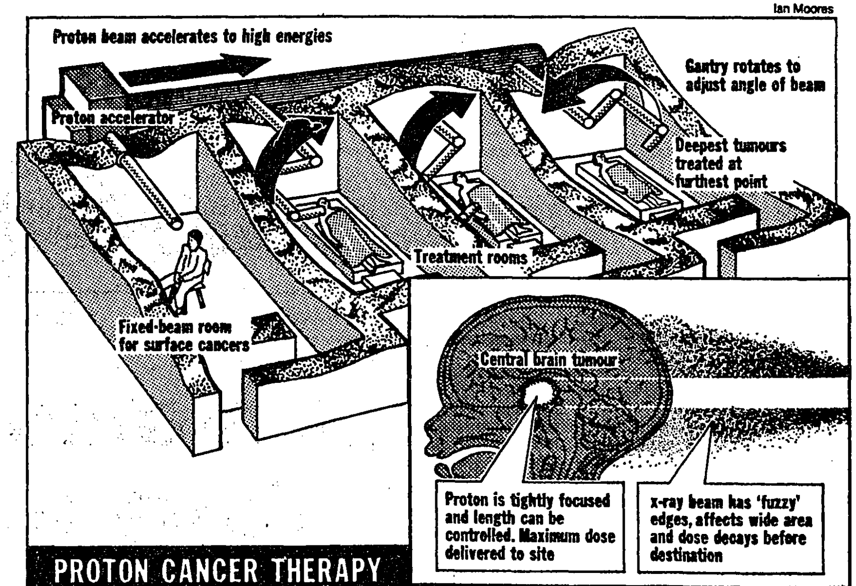

the beam needs to be fired from three angles.

"If you turn the patient over all the organs flop to one side and the accuracy can be so poor you may even miss the tumour," says Griffiths. "To get good medical effects you need to be able to direct the beam from any angle from a gantry that can be rotated round the patient. Ideally you need a patient to be immobilised in a type of straitjacket, and move the beam around."

Beams of higher energy are also needed so that they can penetrate further into the patient to treat the really deep-seated tumours. Until now the maximum acceleration of protons available has been 180MV which sends them less than 15cm (6in) into the body.

Even so, 8,500 people have received proton cancer treatment in Japan, the Soviet Union, Sweden, Switzerland, and Boston, Massachusetts. Many of the patients were in their thirties and if they had not had this option they would have had little chance of survival.

In Britain there is one small facility at Clatterbridge where the neutron machine has been adapted to produce very-low-energy protons of 60MV which penetrate only a few centimetres and are used to treat eyes. So far it has treated about 30 patients for ocular melanoma where previously the eye would have had to be removed.

Later this month the world's first proton-treatment centre designed specifically for medical use will open at Loma Linda University Medical Centre, near Los Angeles. It creates the beam in a circular accelerator with eight magnets forming a ring about six metres across. These fire the protons round the ring many times, enabling them to pick up energy from the electric fields. When they reach the desired energy level they are directed to the delivery point. It is the first time rotating gantries have been used to deliver charged particles.

But AEA Technology believes it has a more compact design that could undercut the £42m equipment cost of the Loma Linda centre by 10-20%, and be much cheaper to operate.

"The Loma Linda centre is overdesigned. It has taken a standard high-energy physics experiment machine and added all the bits needed for medicine. It is enormous and much more expensive than it would need to be if the design were optimised for the application," says Griffiths.

The particle-beam laboratory at AEA Technology started designing very high intensity beams for heating the plasma inside fusion reactors to millions of degrees. It uses hydrogen atoms that have been stripped of their electrons to leave positively charged protons that can be accelerated by very strong electrical fields the length of the machine.

The design the team came up with for hospitals has a structure like a long corridor alongside four treatment rooms.

It is a linear accelerator, instead of circular or cylindrical like the cyclotrons that are being used in Britain. Different energies of proton beam can be extracted at points along it.

For instance, quite a shallow beam might be needed for the head and neck, and a much deeper one for prostate or abdomen tumours.

The ability to treat four people simultaneously helps to make the facility more economic. Griffiths estimates it could treat 1,000 patients a year at less than £20,000 a patient. "This sounds expensive, but is cheaper than a heart transplant, or equivalent to keeping a kidney patient on dialysis for two years," he says.

Some scientists believe that in the long term protons will be superseded in the treatment of cancer by heavier atomic nuclei of elements such as carbon and oxygen.

These contain neutrons as well as protons and combine the advantages of the two sub-atomic particles. They need to be accelerated to even higher energies than protons. But like neutrons, they are more effective on cancerous tissue.

"We could have gone for the heavier atomic nuclei but this is still regarded as a research field. We felt we should go for something of more practical application that could treat patients immediately," says Griffiths.

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