An introduction to different types of radiotherapy

Radiotherapy can cure cancer. It is delivered to around half of cancer patients and is a vital part of curative treatment in around 40% of patients\(^1\). In the UK just over 300,000 new cases of cancer occur each year, and over 90,000 receive radiotherapy as part of their curative treatment\(^2\).

Radiotherapy kills cancer cells because it damages DNA. Cancer cells are more prone to damage than normal cells because of their high multiplying rate and their reduced ability to repair themselves. Radiotherapy is usually given using X-rays; therefore getting radiotherapy is very similar to getting an X-ray.

- **Radiotherapy beams** are usually X-rays given at a higher dose than normal X-rays and are pointed directly at the cancer.
- A **radiotherapy treatment session** is where a number of radiotherapy beams are given one after the other, each pointing at the cancer from a different angle. A radiotherapy treatment session usually takes around 10-30 minutes.
- A **radiotherapy treatment course** is the number of radiotherapy treatment sessions required to complete the curative radiotherapy course. In a typical radiotherapy course, there are around 20 - 40 daily radiotherapy treatment sessions spread over 4 - 8 weeks.

**External Beam Radiotherapy (EBRT)**

External beam radiotherapy is the traditional method of giving radiotherapy and still the best treatment in many cases. The patient lies on a radiotherapy bed in the same position every day for a radiotherapy treatment session. In each session, between 2-4 radiotherapy

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[http://info.cancerresearchuk.org/prod_consump/groups/cr_common/@nre/@sta/documents/generalcontent/cr_072111.pdf](http://info.cancerresearchuk.org/prod_consump/groups/cr_common/@nre/@sta/documents/generalcontent/cr_072111.pdf)
beams are given. A radiotherapy beam is switched on to deliver the beam. Then the radiotherapy machine moves into a different position before giving the next beam from a different angle. The machine that gives the radiotherapy is called a linear accelerator (or a “linac”).

Before we start radiotherapy we design a treatment plan. This is when we arrange at which angles to put the beams. We do this by doing a CT scan to get a 3-dimensional picture of the cancer inside the body. Computer software programs are used to decide how to point the radiotherapy beams so that when the beams come together inside the body, they hit the cancer to give the most powerful effect.

New Radiotherapy Techniques

Radiotherapy would kill a cancer every time if a big enough dose could be given to the cancer. But sometimes doctors cannot give a big enough dose because they don’t want to damage the normal cells around the cancer. We are always trying to improve our radiotherapy techniques so that we can

1) Cure more cancers
2) Cause fewer side effects.

Below are some of the new techniques available to help us do that. These techniques are often used together to make the radiotherapy course as effective as possible, as usually doctors have one opportunity to cure cancer with radiotherapy.

1 Intensity-Modulated Radiation Therapy (IMRT)

Intensity-Modulated Radiation Therapy (IMRT) is a way of giving radiotherapy that enables doctors to precisely shape the radiation beam around the cancer while keeping the dose away from normal cells. IMRT can also give a bigger dose to the more aggressive parts of a cancer at the same time as a normal dose to the less aggressive bits. IMRT is done by using
more radiotherapy beam angles, usually about five to 10. In the same way as with EBRT, the linac moves into different positions between each radiotherapy beams. Once it is in position, the radiotherapy beam is switched on for a few minutes before it stops and moves again.

With IMRT we give the radiotherapy more exactly around the tumour. This means there is a lesser dose given to normal cells therefore reducing side effects. In the future we may be able to give bigger doses because with IMRT we are better at hitting fewer normal cells.

2 Volumetric Modulated Arc Therapy (VMAT)

Volumetric Modulated Arc Therapy (VMAT) treatment is very similar to IMRT. Instead of the linac moving into different positions before the radiotherapy beam is switched on, it stays switched on the whole time as the linac moves around the patient in an arc. It produces the same result as IMRT but is up to eight times faster.

VMAT is also known as Rapidarc.

3 Image Guided Radiotherapy (IGRT)

Image Guided Radiotherapy (IGRT) is the use of different types of pictures to help improve the number of times we hit the cancer and to make sure we miss the normal cells.

Tumours move between daily treatments, because of daily changes inside the body. An example of this is when the bladder changes size and position depending on whether it is full of urine or empty. With IGRT, the linac is able to take a picture of the cancer while the patient lies on the radiotherapy bed just before radiotherapy. We can then adjust the beams so that they line up exactly with the cancer inside. If the cancer has moved a lot between daily treatments, these pictures show us this and we put a new set of beams on to hit the cancer better.
Cancers also move while a linac is on. An example of this is lung tumours move up and down because of breathing. We can check the amount of movement by doing special CT scans that allow us to see the tumour moving called 4 dimensional CT scans. We can also check the movement with the pictures taken immediately before the radiotherapy to make sure it has not changed a lot from when we put the beams.

Another form of IGRT is the use of different scans such as MRI scans and PET/CT scans in the planning of radiotherapy to make sure the beams are pointed in the right direction.

IGRT enables doctors to hit cancers more accurately and hit fewer normal cells.

4 Stereotactic Ablative Body Radiotherapy (SABR)

Stereotactic Ablative Body Radiotherapy (SABR) is also known as Stereotactic Body Radiotherapy (SBRT).

SABR is different to normal radiotherapy because instead of giving a little radiotherapy everyday over four to eight weeks, we give a big dose over only three to five days. This adds up to a much bigger dose overall so it is better at killing the cancer and cures more people.

There are different ways of giving this treatment depending on what radiotherapy machines your local hospital has. SABR can be given using a linac, VMAT or Rapidarc. Another machine that gives SABR is Cyberknife. All of these techniques are equally as good. Whichever technique you use, IGRT is an important part of SABR treatment.

In some cancer types such as lung cancer, studies have shown that SABR cures more people than EBRT. In other cancer types it remains more experimental, but looks to be an excellent treatment given with the aim of either cure or control.
5  Radiosurgery

Radiosurgery is the delivery of high doses of radiotherapy to cancer in the brain. It is usually used to treat cancers that have started in other parts of the body and have spread to the brain. It is called radioSURGERY because it can be given all in one day, like an operation. But it can also be given over two to five days. These treatments have to be very precise, so often patients’ heads are held steady inside a special box, or inside a special mask to make sure they do not move.

Different machines that can all give radiosurgery include: a linac, the Gamma Knife, VMAT, Rapidarc and Cyberknife. They are all equally as good as each other.

In the same way as SABR, radiosurgery gives a bigger dose than we could give with EBRT. It can be given with aim of cure or control.

6  Proton Therapy

Proton therapy is a form of radiotherapy that does not use traditional X-rays. Proton beams are different because they do not go all the way through the body, they stop at the area of the cancer and deliver most of the dose to that area.

Protons are usually used for radiotherapy treatment courses where the nearby normal cells are so sensitive to radiotherapy it would be impossible to give radiotherapy if we used X-rays. The kind of normal cell that is very sensitive is any normal cell within a child and brain or spinal cord cells. As a result the kinds of cancers that are treated with proton therapy are childhood cancers and cancers of the brain or spine.

Proton therapy is usually used in these cancers to give a curative dose when EBRT would be too dangerous to use.
Proton therapy can be used in other cancers to increase the dose because the dose is delivered primarily in the cancer. This is still experimental and usually used within studies.

7 Brachytherapy

Brachytherapy is the delivery of radiotherapy from a radioactive source that is put in or near the cancer. A source is a small piece of metal that when it breaks down it emits radiotherapy. There is no machine involved. Brachytherapy is commonly used in cervical cancer, prostate cancer, breast cancer, and skin cancer and can also be used to treat tumours in many other areas of the body. Brachytherapy can be used alone; before or after other treatments such as surgery, EBRT and chemotherapy.

Depending on the area of cancer, radioactive seeds or sources can be put either in or near the tumour so that the radiotherapy affects the cancer and very little else. This means the normal cells next to the cancer get less dose causing less side effects. Another benefit is that if the patient moves or if there is any movement of the cancer inside the body during treatment, the radiation sources stay in the correct position right beside the cancer. For these reasons brachytherapy does not tend to have a lot of side effects.

A course of brachytherapy is usually done on the ward and can be anything from one to six sessions. Sometimes to get the radiotherapy sources into the tumour, a general anaesthetic is needed; in others it is done with the patient awake.

In some types of cancers, brachytherapy can cure as many people as surgery or EBRT and can be used instead of these other treatments. In others types of cancer, adding brachytherapy to surgery or EBRT allows us to cure more people.

8 Adaptive Radiotherapy
Usually in radiotherapy we use the treatment plan decided at the beginning of treatment all the way through the treatment course. In adaptive radiotherapy, we use different scans and pictures taken part way through the treatment to make a new treatment plan. This means we can hit the tumour better if it moves or if the cancer shrinks we could make our beams smaller so we hit fewer normal cells.

This technique makes us hit the cancer better and could potentially allow us to reduce the dose to the normal cells. If we reduce the dose to normal cells we could increase the dose to the cancer.

9 Intra-operative radiotherapy (IORT)

Intra-Operative Radiotherapy (IORT) is usually for patients who have had their cancer removed with an operation where there is a small chance of left over cancer cells. Usually patients will get EBRT to get rid of these left over cancer cells. With IORT, the radiotherapy is given while the patient is under anaesthetic usually at the time of their cancer operation (although it can be given at a separate operation). The radiotherapy source is put in the bed where the cancer used to be and delivers the radiotherapy directly to the area where there may be left over cancer cells.

There are a number of benefits of IORT. The whole treatment course is completed under one anaesthetic rather than lots of radiotherapy treatment sessions which is far more convenient for the patient. The other benefit is that there are likely to be fewer side effects, because by putting the source near the cancer bed more of the dose goes to the areas where the cancer might be, and the normal cells around the cancer therefore get less dose.

This treatment is only proven to be equivalent to standard EBRT in breast cancer but is being used within scientific trials in other tumours such as cancers of the rectum, prostates and kidney, and sarcomas.
10 Molecular Radiotherapy

Cancer cells take up different molecules to help them grow or develop. Molecular radiotherapy takes advantage of this by creating either a ‘copy cat’ molecule that looks like the one the cancer needs or by making the actual molecule the cancer needs. We then make these molecules radioactive so that they produce radiotherapy. This can be done by making the molecule unstable so it breaks down. These molecules are then injected into the patient and the cancer cells take them up. The molecules that have been taken into the cancer cells then produce radiotherapy and cause the cancer cells to die.

This treatment is used to help cure patients or to help control disease. As it is delivering the radiotherapy in a different way, it is different to traditional radiotherapy and can be used as an additional treatment. Because it is an extra treatment it can often improve survival rates in patients. The other benefit is that because the radioactive molecules are mainly taken up by cancer cells, the normal cells do not get the radiation dose. This means the side effects are less.

It has been used for years in mainly prostate and thyroid cancer. We are now using it more with new molecules for these cancers and different molecules for cancers such as lymphoma, leukaemia, brain and neuroendocrine cancers. We are also using molecules taken up by specific parts of the body like the liver or bone, so that cancers that have spread to this area can be treated in this way.

Put together by Mrs Linda Taylor and Prof Tim Maughan, March 2010
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NCRI Clinical and Translational Radiotherapy Research Working Group (CTRad)