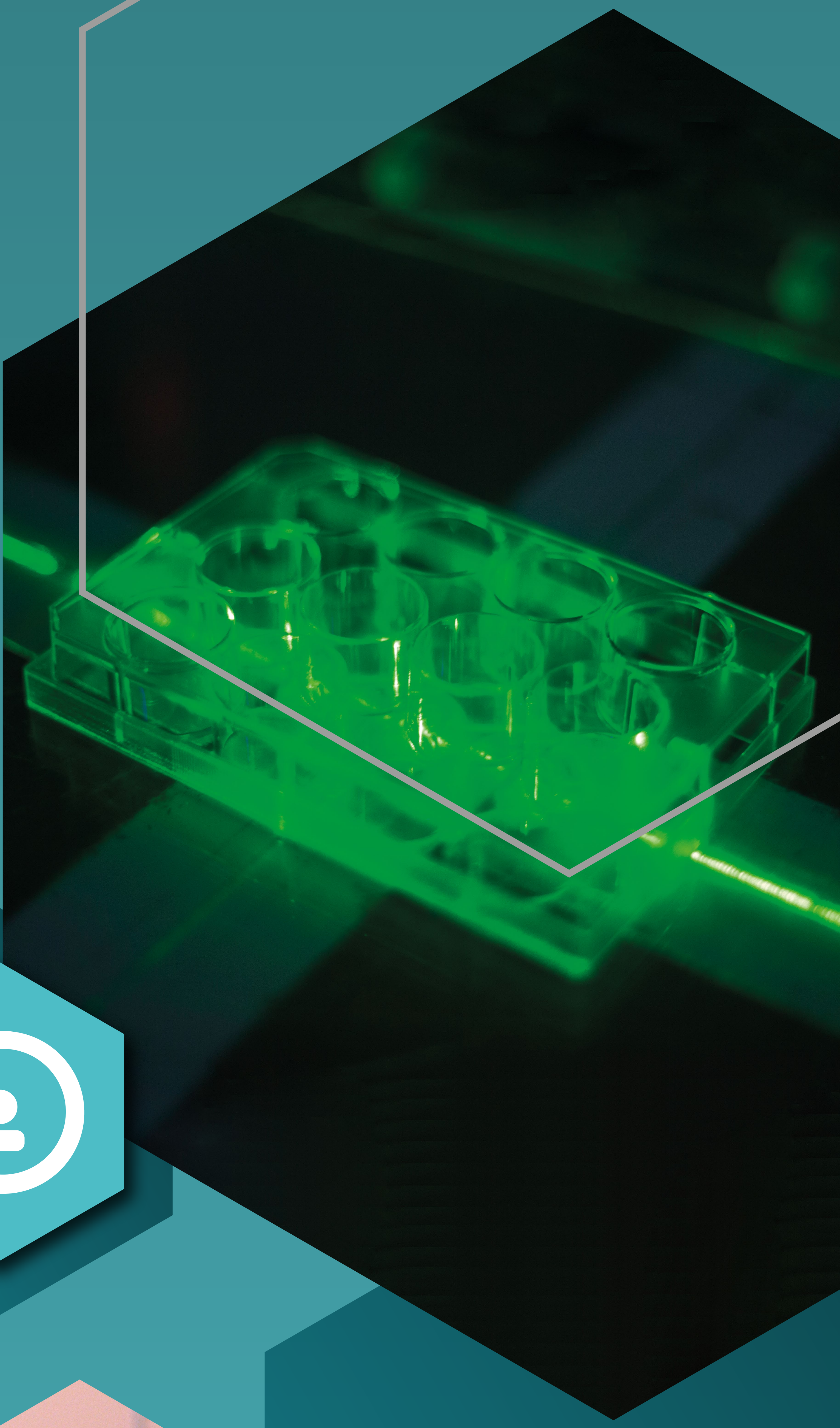
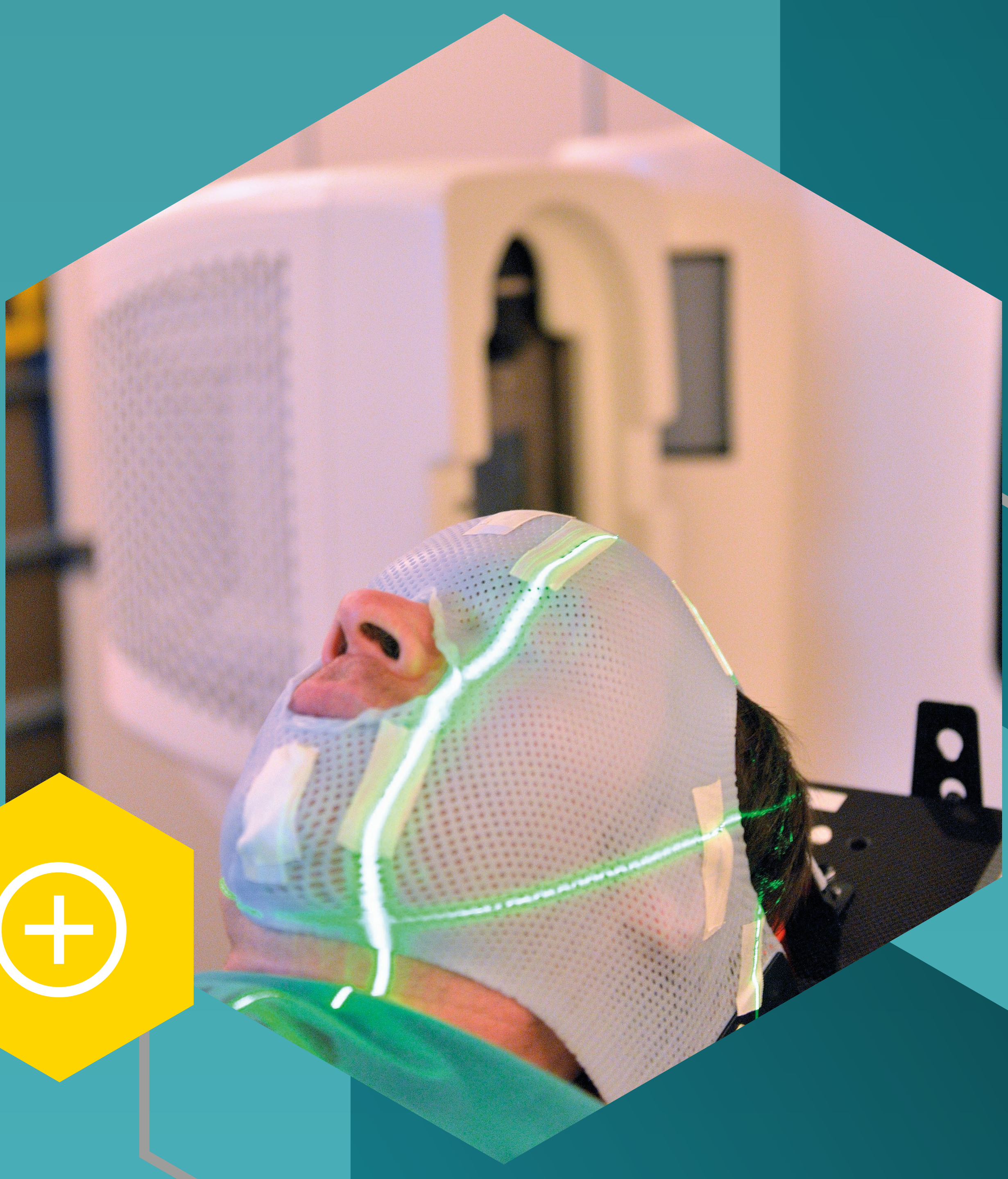
RADIATION FOR HEALTHCARE





5.1 Design: ASN and IRSN Communications Departments - October 2021
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RADIATION FOR HEALTHCARE

RADIOACTIVITY IN HOSPITALS

Ionising radiation and radioactive substances are used to **identify or treat disease**. Precautions must be taken to ensure that the benefits outweigh the risks.

Hospitals are home to diagnostic, production, treatment and management units for the radioactive waste used to treat patients.

DIAGNOSE

X-rays and gamma rays allow the inside of the human body to be viewed without the need for surgery.

This is called **medical imaging.**

IMAGING BY TRANSMISSION...

The patient is placed between a radiation source and a detector. This is the case with conventional X-rays and scans, which use X-rays.

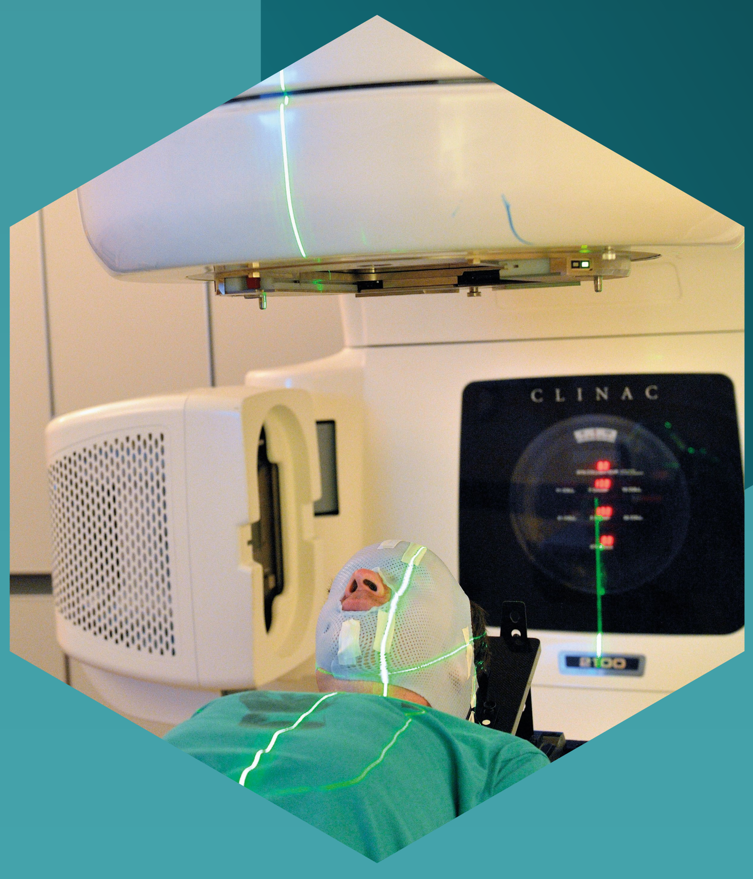
The rays are attenuated to a greater or lesser extent depending on the parts of the body they pass through. Tumours, fractures and infections interact differently with the rays, producing different images that doctors are able to recognise.

...OR BY EMISSION

The patient is injected with a radioactive substance.

The substance travels to a specific area and emits gamma rays from inside the body.

Outside, the rays are captured by a camera. This is the case with scintigraphy.



TREAT

Radiation can be used directly for treatment.

The aim of irradiation is to destroy a cancerous tumour, for example, while sparing healthy tissue.

This process is known **as radiotherapy**.

DEBATE

RADIATION,
NO MORE
THAN NECESSARY

Radiology is a bit like antibiotics: it should not be used systematically.

Healthcare professionals must ensure that they do not automatically resort to ionising radiation when there are alternative solutions, such as magnetic resonance imaging (MRI) or ultrasound, which do not present any risks.

France has fewer than 14 MRI machines per million inhabitants, while the average in Western Europe is close to 20.

Every year, tens of millions of X-rays and scans are carried out in France and more than 200,000 people are treated with radiotherapy.

The use of ionising radiation in the medical field is genuinely effective. Over the period 1989-2010, there was an improvement in standardised 5-year net survival rates for most cancers.

5.2 Design: ASN and IRSN Communications Departments - October 2021
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RADIATION FOR HEALTHCARE

DIAGNOSE

To reveal the inside of a body, we can introduce radioactivity or temporarily expose it to radiation. However, doses must be carefully controlled.

IMAGING BY EMISSION

The patient is injected with a radioactive product called a tracer 1. The tracer is chosen so that it binds to the organ to be studied.

Like a lamp in the dark, the radiation emitted by the tracer provides an image of the organ inside the body.

This procedure uses products that quickly lose their radioactivity: only the minimum amount of radioactivity needed is injected into the patient, minimizing their exposure.

EXAMPLES OF TECHNIQUES

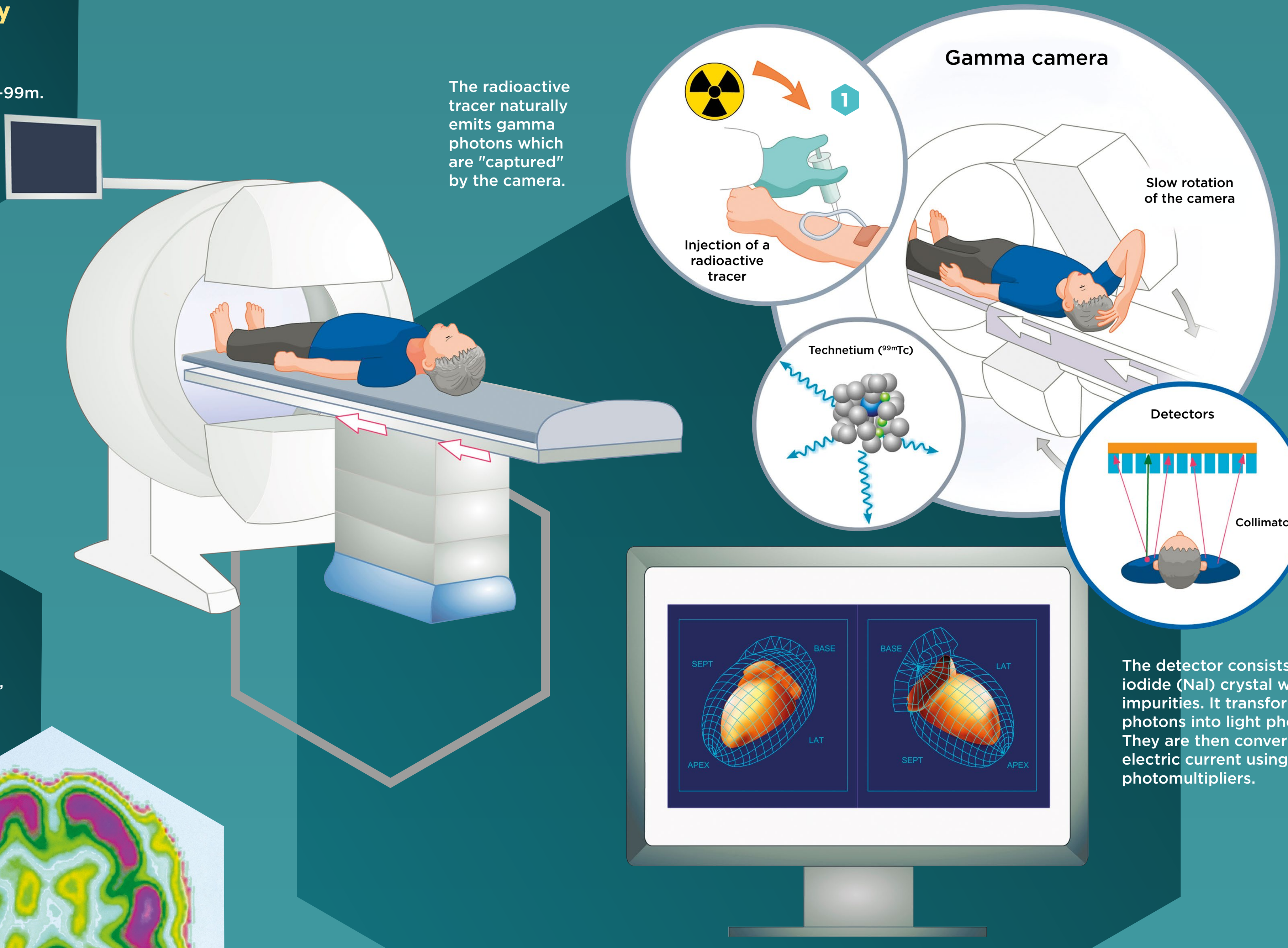
Conventional scintigraphy or single-photon emission computed tomography (SPECT)

Example of diagnosis: thyroid.

Tracer: iodine-123 or technetium-99m.

Radiation emitted: gamma.

Average dose: 4 mSv.



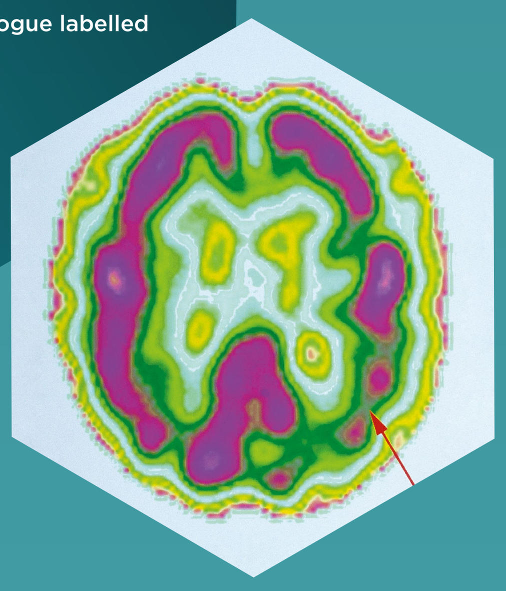
The detector consists of a sodium iodide (NaI) crystal with thallium (Tl) impurities. It transforms gamma photons into light photons. They are then converted into an electric current using photomultipliers.

Positron emission tomography (PET)

Example of diagnosis: brain diagnosis, Alzheimer's disease.

Tracer: a glucose analogue labelled with fluorine-18.

Average dose: 7 mSv.



IMAGING BY TRANSMISSION

The patient is irradiated directly with X-rays. By placing a detector behind the patient, we can draw up a map of the inside of the body. The denser the tissue, the more it attenuates the rays. Bones and tumours are clearly visible.

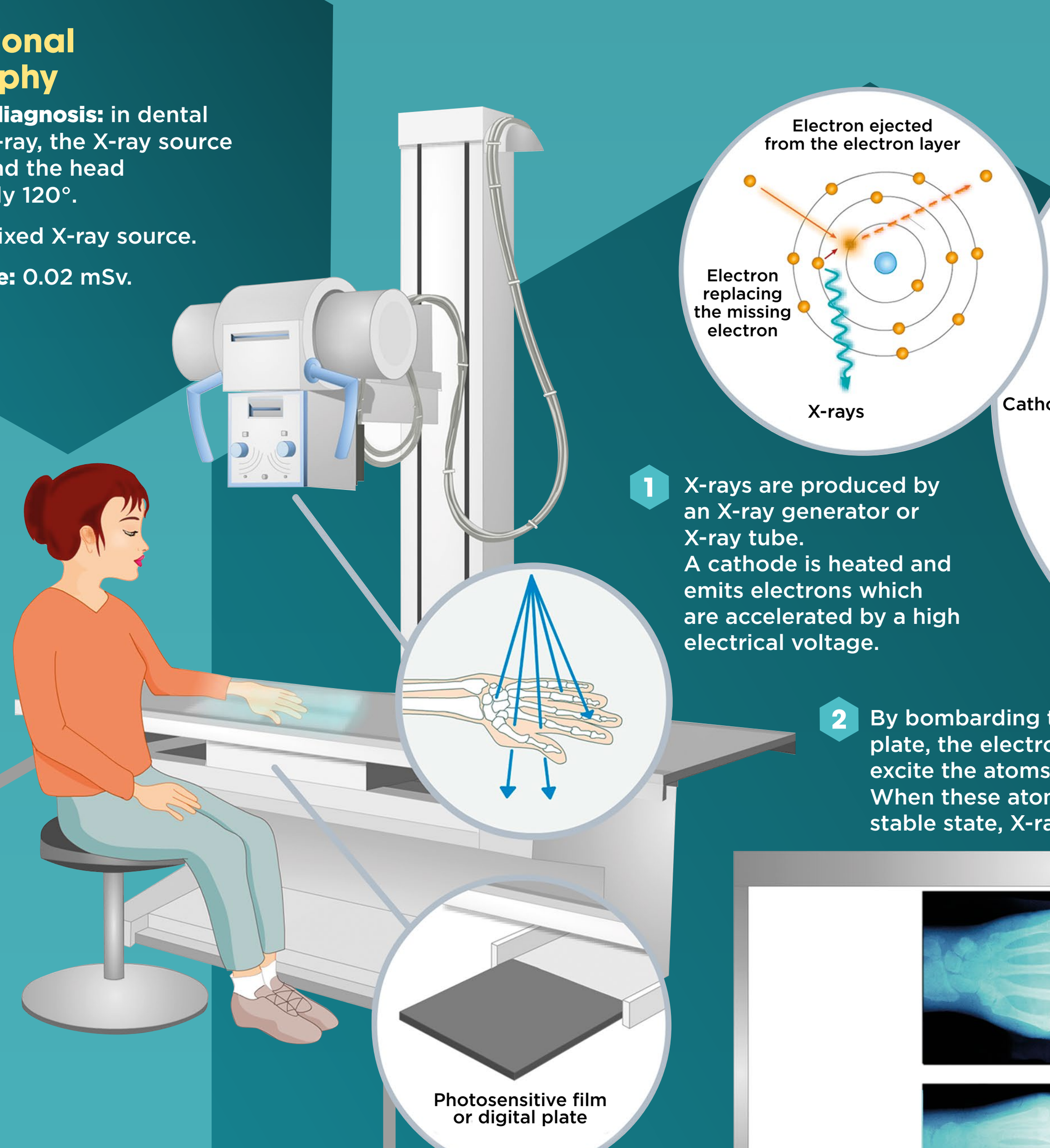
EXAMPLES OF TECHNIQUES

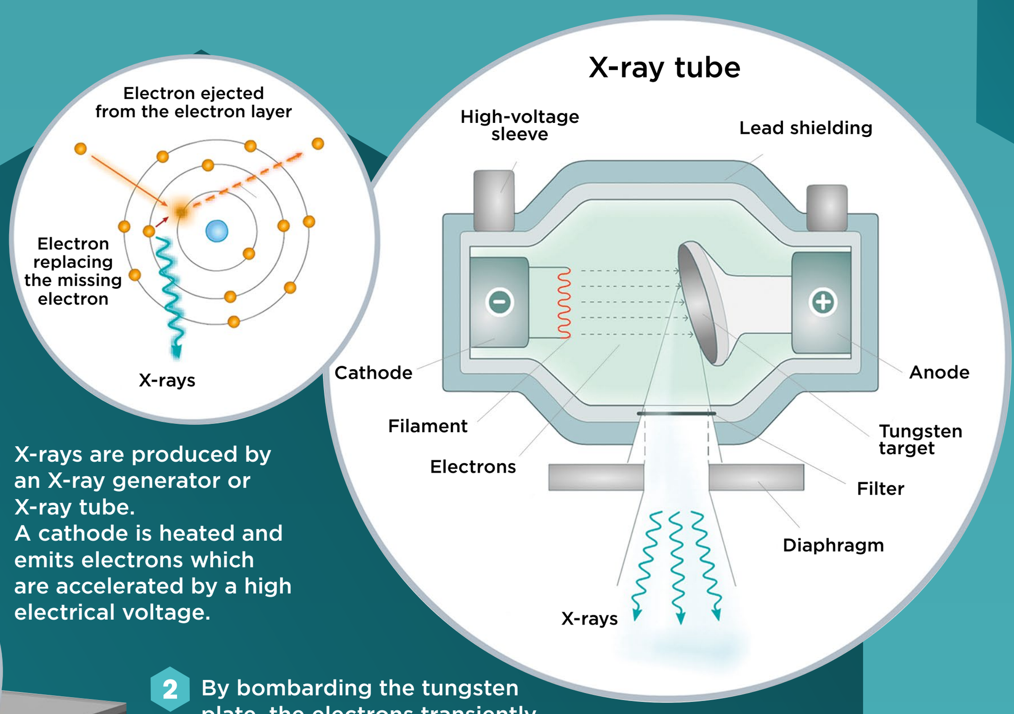
Conventional radiography

Example of diagnosis: in dental panoramic X-ray, the X-ray source rotates around the head approximately 120°.

Specificity: fixed X-ray source.

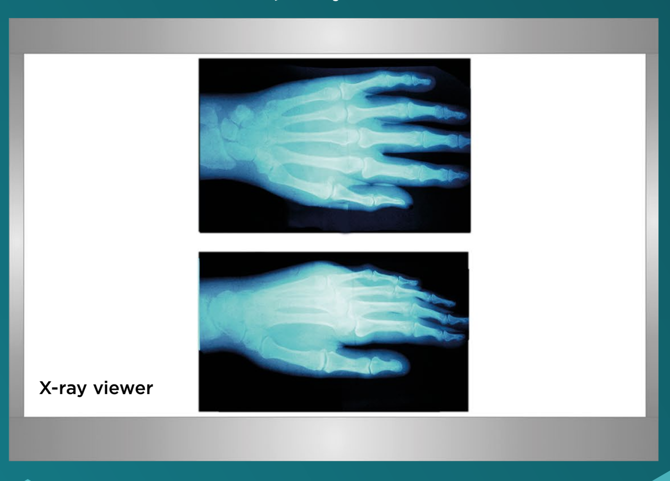
Average dose: 0.02 mSv.





1 X-rays are produced by an X-ray generator or X-ray tube. A cathode is heated and emits electrons which are accelerated by a high electrical voltage.

2 By bombarding the tungsten plate, the electrons transiently excite the atoms in the plate. When these atoms return to a stable state, X-rays are emitted.



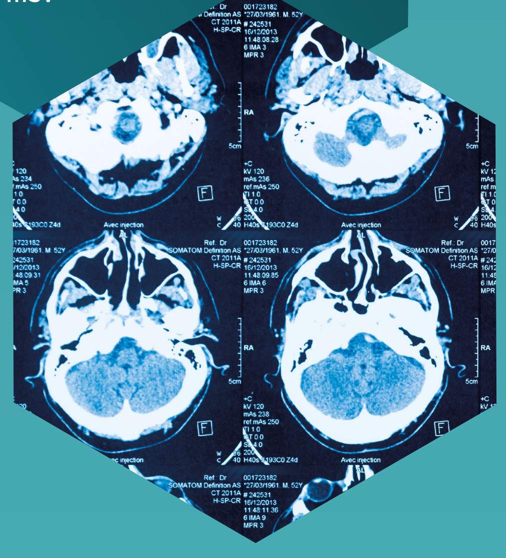
3 The images are produced by irradiating the organ with X-rays. Photons passing through the organ are stopped by a detector on the other side. The quantity of photons absorbed depends on the chemical composition of the tissues passed through. The denser the tissue, the more it blocks photons.

The scanner

Example of diagnosis: thoracic scanner

Specificity: mobile X-ray source. Allows for cross-sectional X-rays (by slice) and 3D reconstruction.

Average dose (chest scan): 5 to 10 mSv

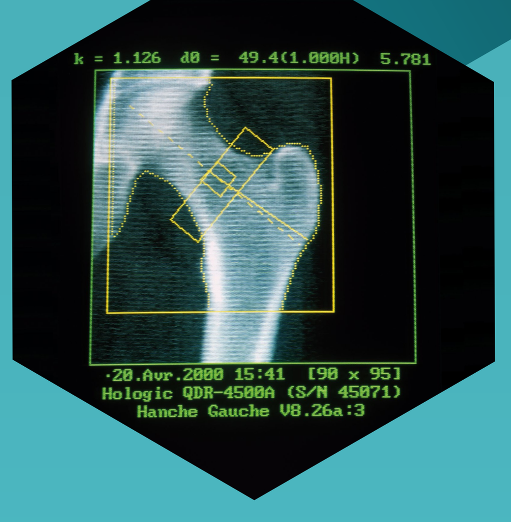


Bone densitometry

Example of diagnosis: hip

Specificity: two X-ray sources. Measures bone mineral content and density.

Average dose: 0.001 mSv



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RADIATION FOR HEALTHCARE

TREAT

The **destructive power** of radiation is used to treat tumours. Working like a kind of laser, they are capable of reaching and destroying tumours inside the body. There are several treatment methods.

EXTERNAL **RADIOTHERAPY**

is a treatment used in more than half of all cancer patients.

It involves focusing radiation from a particle accelerator or X-ray generator on cancer cells, in order to destroy them or stop them from multiplying.

IN BRACHYTHERAPY,

a radioactive source is temporarily or permanently placed inside the patient. The source then delivers radiation locally to the tumour to be treated.

Brachytherapy is commonly used to treat cervical, prostate and skin cancer. Only in the case of prostate cancer does the source remain permanently in place.

RADIOSURGERY AND STEREOTACTIC RADIOTHERAPY

are external radiotherapy techniques that use high-dose, ultra-precise radiation, like an intangible scalpel, to destroy a tumour. Precision is greater than with conventional radiotherapy.

These include the Gamma Knife®, CyberKnife® and multileaf collimators. In 2019, there were 19 CyberKnife® and 5 Gamma Knife® systems in France.

METABOLIC RADIOTHERAPY

The patient is given a radioactive product that will bind to the target organ. The technique is similar to scintigraphy.

Substances are used to irradiate the diseased cells as locally as possible, preventing the radiation from reaching healthy cells as much as possible.

DEBATE

BENEFITS AND DANGERS OF RADIOTHERAPY

Radiotherapy is truly effective. More than 200,000 people are treated each year.

Very precise protocols enable the radiation to be concentrated on the diseased tissue to avoid affecting other organs and prevent the appearance of secondary cancers. The dose is divided into several sessions and irradiation is performed at different angles.

Considerable progress has been made in this area in recent years.

Radiotherapy uses high doses of radiation.

There is a risk of causing lesions, or even secondary cancer, if healthy tissue and organs surrounding the tumour, which may be organs at risk, are irradiated.

5.4 Design: ASN and IRSN Communications Departments - October 2021
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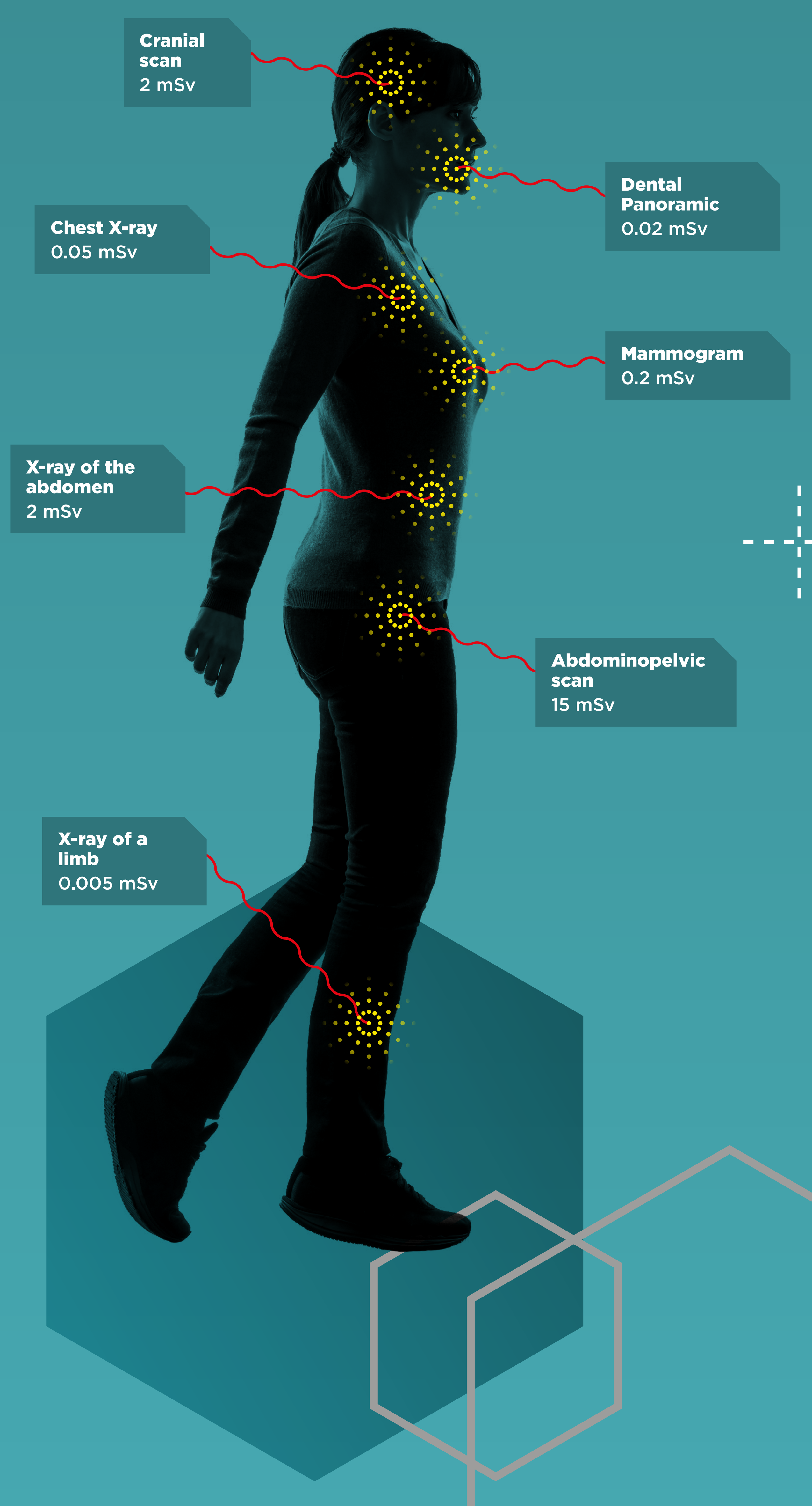
RADIATION FOR HEALTHCARE

MEDICAL IMAGING: LIMITING DOSES

Beware of the **proliferation of unjustified examinations.**

CAUTION
WITH X-RAYS AND SCANS

Although used for medical purposes, radiation presents risks and must be used with caution.



A FEW TIPS
FOR PATIENTS

X-RAYS ARE NOT SYSTEMATIC

Don't ask your doctor for an X-ray or scan just to get reassurance. Only your doctor can decide whether such an examination is worthwhile.

In addition, ask your doctor why, in your case, an X-ray or CT scan is preferable to imaging that does not use X-rays, such as an ultrasound or MRI.

BE VIGILANT

Keep your X-rays and examination reports and bring them to your appointments. If they are recent, you may not need to redo them. In addition, make sure that the radiation dose received during the examination is included in your report, for better monitoring.

TAKE PARTICULAR CARE OF YOUNG PEOPLE

Because their organs are still growing, children are more sensitive to X-rays than adults. Particular attention should therefore be paid to young children and pregnant women.

A FEW TIPS
FOR HEALTHCARE WORKERS

MINIMISE EXPOSURE TIME

Do not stay in the room when an X-ray is being taken.

PROTECT YOURSELF

Use personal protective equipment that absorbs radiation: wear lead aprons, leaded goggles and thyroid shields, and use movable leaded screens.

INCREASE DISTANCE

Multiplying the distance by 2 divides the dose received by 4. Practical example: using tongs to handle radioactive sources.

Increased doses

Medical imaging (scanners, etc.) is used more and more often around the world.

While the use of increasingly high-performance imaging technology is making it possible to reduce the dose received, we still need to **remain vigilant!**

ANALYSES
IN FRANCE

Scan the following QR codes to find out more:

- analysis of diagnostic exposure of French population
- analysis of doses received by patients in France

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RADIATION FOR HEALTHCARE

RADIOTHERAPY: CONTROLLING RISKS

Skills, protocols and **highly supervised** equipment.

THE GRAY
is used to measure the energy due to the amount of radiation received.

RADIOTHERAPY: PROPER CONDUCT

CONTROLLING THE RISK/BENEFIT RATIO

In radiotherapy, the doctor must optimise the dose to ensure that:

- the chance of permanently destroying diseased tissue or a cancerous tumour is maximised. This is the notion of a **control dose**;
- the risk of causing secondary complications or cancers is minimised. This is the notion of a **tolerance dose**.

If the prescribed dose is kept to a minimum, healthy tissue is protected, but there is a risk that the patient will not be treated (under-irradiation).
Conversely, prescribing too high a dose increases the effectiveness of the treatment, but runs the risk of generating undesirable side-effects.
The aim is therefore to find a compromise between treatment efficacy and side effects.

SPACING OUT DOSES

The doctor must spread the dose over several sessions to allow the healthy tissue to regenerate.

MASTERING TECHNOLOGY

Equipment must be carefully adjusted and maintained.

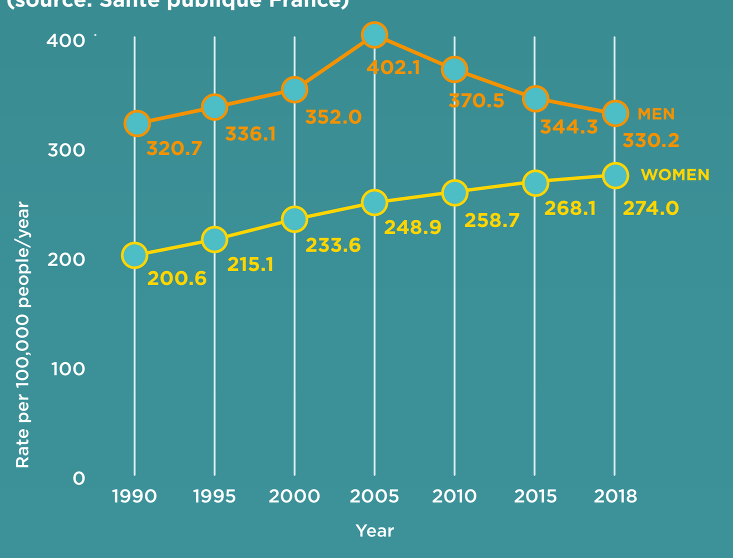
REGULAR CHECKS

ASN regularly inspects all radiotherapy centres, paying particular attention to human and organisational factors. ASN raises awareness among professionals through publications and training courses.

FIGURES FOR CANCERS DETECTED

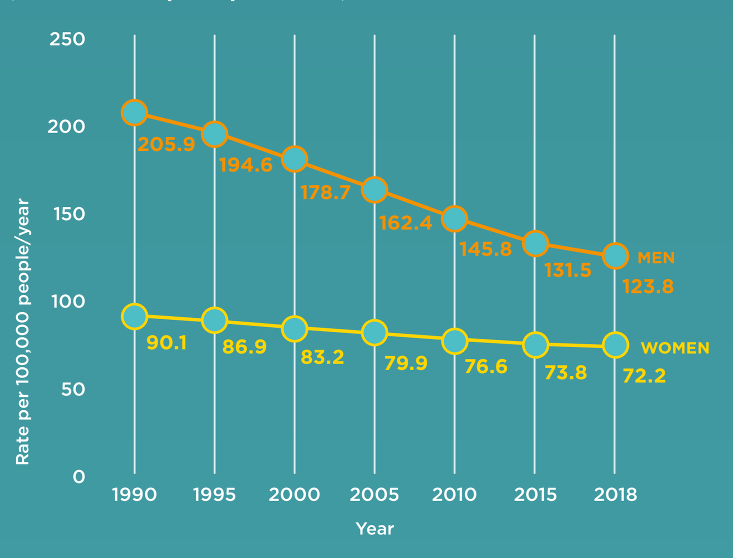
The number of cancers has increased over the last thirty years. This increase is due in particular to the ageing of the population and to advances in diagnostic techniques.

Change in cancer occurrence from 1990 to 2018 by sex (source: Santé publique France)



However, mortality from cancer has decreased as a result of advances in medical techniques.

Trends in cancer mortality from 1990 to 2018 by sex (source: Santé publique France)



The 5-year survival expectancy following cancer remains very uneven today. Some cancers are very well treated, such as prostate cancer, but others, such as lung cancer, are fatal for more than 8 out of 10 patients.

More than 200,000 patients are treated with radiotherapy every year in France.

IRRADIATED BUT NOT CONTAMINATED!
In external radiotherapy, once the session in the treatment room is over, the patient does not take any radioactivity with him or her. There is **no risk** to those around them.

Visit the **e-cancer.fr** website to download the **patient guide** (under the heading "Expertises et publications") and find out more about **treatment** methods **and side effects** (under the heading "Patients et proches/Se faire soigner").
Scan this QR code to access it.

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RADIATION FOR HEALTHCARE

ACCIDENTS IN RADIOTHERAPY

Errors in positioning and dosage have already been made in radiotherapy in France and around the world. Checks must be carried out regularly and feedback taken into account.

A GRADING SCALE

The ASN-SFRO scale provides information on the seriousness of radiotherapy events: patient positioning error, dose error, etc.

EVENTS
In the event of death of several patients:
• minimum level 5 is raised to 6 if the number of patients is between 2 and 10;
• minimum level 5 is raised to 7 if the number of patients exceeds 10.

EVENT
If the number of patients is greater than 1:
• a "+" sign is added to the level selected (example: 3 becomes 3+).

ACCIDENT

7

6 DEATH

5 DEATH

CAUSES Dose or irradiated volume much higher than normal, leading to complications or after-effects that are not compatible with life.
CONSEQUENCES Death

4 SERIOUS EVENT life-threatening, disabling complications or after-effects.

CAUSES Dose or irradiated volume well in excess of tolerable doses or volumes.
CONSEQUENCES Serious, unexpected or unpredictable acute or late effect, grade 4.

INCIDENT

3 EVENT CAUSING severe deterioration of one or more organs or functions.

CAUSES Dose or irradiated volume higher than tolerable dose or volume.
CONSEQUENCES Severe, unexpected or unpredictable acute or late effect, grade 3.

2 EVENT CAUSING OR LIKELY TO CAUSE moderate deterioration of an organ or function.

CAUSES Dose greater than the recommended doses, or irradiation of a volume that may lead to unexpected but moderate complications.
CONSEQUENCES Moderate, unexpected or unpredictable acute or late effect, grade 2, with minimal or zero deterioration in quality of life.

EVENT

1 EVENT WITH DOSIMETRIC CONSEQUENCES but no expected clinical consequences.

CAUSES Error in dose or volume, for example :
• dose error or target error in one treatment session that cannot be compensated for over the entire duration of treatment;
• misidentification of patients treated for the same condition (can be compensated for).
CONSEQUENCES No symptoms expected.

0 EVENT OF NO CONSEQUENCE for the patient.

ÉPINAL ACCIDENT 2004/2005

Between May 2004 and August 2005 at the Jean-Monnet hospital in Épinal (Vosges), 24 patients treated for prostate cancer received too high a dose because of incorrect use of the treatment scheduling software.

Some of them died as a result of this overexposure. The investigation revealed that other malfunctions had caused the overexposure of 5,000 patients.

Aujourd'hui en France , 13/10/2006

TOULOUSE ACCIDENT 2006/2007

Between April 2006 and April 2007, calibration errors on the radiosurgery equipment at Toulouse University Hospital led to the overexposure of 145 patients.

Some suffered severe neurological complications as a result of the accident.

Aujourd'hui en France, 23/05/2007

LESSONS FROM THE PAST

Following the serious accidents in Épinal and Toulouse, the public authorities took drastic measures:

- examination of the practices of 178 private and public radiotherapy centres, resulting in the merger or closure of those that did not comply with the requirements;
- recruitment of additional medical physicists, specialised in the management of radiation and associated equipment;
- large-scale renewal of equipment and increase in the number of treatment units;
- specialisation of the accelerators available with the appearance and distribution of dedicated machines;
- obligation to monitor patients for 5 years after the end of treatment;
- obligation to report any incident or accident to ASN;
- obligation for centres to formalise practices (quality assurance);
- obligation for centres to analyse all malfunctions, including minor ones.

ASN INSPECTORS AND IRSN EXPERTS

The use of radioactive substances and radiation in hospitals creates a risk that needs to be managed.

ASN and IRSN therefore carry out inspections and expert assessments in the interests of both patients and healthcare staff.

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RADIATION FOR HEALTHCARE

THE PRODUCTS **USED**

Many radioactive substances are used in hospitals. They each have specific characteristics that make them effective for particular organs.

WHICH PRODUCTS FOR WHICH USES?

TECHNETIUM-99M (INJECTION)

Half-life: 6.02 hours

Technetium-99m is the product most commonly used in medical imaging. Combined with different molecules, it can be used to explore a large number of organs (thyroid, bones, heart, kidneys, lungs, etc.).

Its half-life is long enough to monitor physiological processes, but short enough to limit patient irradiation.

The energy of its radiation is ideal: sufficient to penetrate living tissue and to be easily detected, but low enough to limit patient exposure.

IODINE-123 (INJECTION)

Half-life: 13 hours

Iodine-123 is an isotope of iodine used to study the thyroid because it binds naturally to it. Its low-energy gamma photon radiation and short half-life make it well suited to imaging.

IODINE-131 (CAPSULE / RADIOTHERAPY)

Half-life: 8.2 days

Iodine-131 is another isotope of iodine. Its radiation rich in beta particles and its relatively long half-life make it ideal for treating thyroid disorders.

It is used to remove overactive thyroid nodules, to treat certain forms of hyperthyroidism, and to find and remove thyroid tumours.

SAMARIUM-153 (INJECTION / RADIOTHERAPY)

Half-life: 46.8 hours

Samarium-153 is used in symptomatic radiotherapy, mainly to relieve pain caused by bone metastases from cancer.

FLUORINE-18 (INJECTION)

Half-life: 110 minutes

It is used in medical imaging. Its rays travel only a short distance through the body, giving a precise image. Its half-life is very short, less than 2 hours, which limits contamination and patient exposure.
It is mainly used in oncology.

THALLIUM-201 (INJECTION)

Half-life: 3 days

Thallium-201 is a radioactive isotope used in cardiac scintigraphy. Used for a long time, it is starting to be abandoned in favour of more recent markers.

YTTRIUM-90 (INJECTION/RADIOTHERAPY)

Half-life: 2.7 days

Yttrium-90 is used in radiotherapy.
It is injected into patients in the form of microspheres, mainly to treat liver cancer. The resin microspheres will attach themselves to the capillaries of the liver and those supplying the tumour to be destroyed.

GALLIUM-68 (INJECTION)

Half-life: 68 minutes

This isotope is similar to fluorine-18 in its physical characteristics and is used in the same way as fluorine-18 for medical imaging in oncology. Its current main application is the diagnosis of digestive neuroendocrine tumours. It should soon be approved in France for the diagnosis of prostate cancer.

INDIUM-111 (INJECTION)

Half-life: 2.8 days

An indium-labelled tracer can be injected to image cerebrospinal fluid production, migration and reabsorption.

The indium tracer attached to the patient's white blood cells can also be used to detect infection.

LUTETIUM-177 (INJECTION/RADIOTHERAPY)

Half-life: 6.7 days

Like iodine-131, this isotope emits beta particles and has a relatively long half-life, making it ideal for therapy. It is currently used in the treatment of digestive neuroendocrine tumours. It is due to be approved shortly in France for the treatment of prostate cancer.

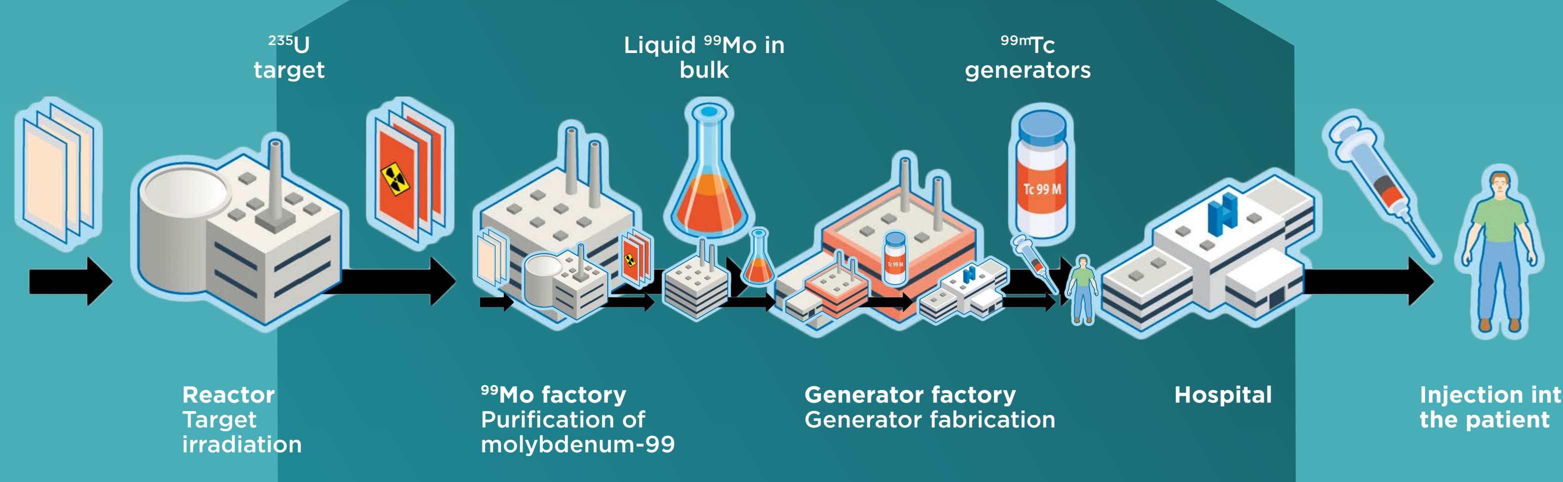
HALF-LIFE

The half-life of radioactive material is the time after which half of the original atoms have decayed.

AND BEFORE THE PRODUCTS ARE ADMINISTERED?

The relatively short lifespan of the isotopes used in the medical sector means that frequent deliveries have to be made to hospitals. Around 30% of packages containing radioactive substances are transported for medical purposes.

MAKING TECHNETIUM-99m



Technetium-99m has a very short lifespan.
It must be prepared a few hours before use, hence the importance of having a production centre within hospitals.

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