Brachytherapy

Two major categories for the application of radiation for cancer treatment are **external-beam therapy** and **brachytherapy**. For external-beam treatment, the patient lies underneath a machine that emits radiation or generates a beam of x-rays. This tech-nique is **also called teletherapy**, or **long- distance treatment**. Most cancer patients are treated in this fashion. However, some pa-tients may also be treated with brachyther-apy.

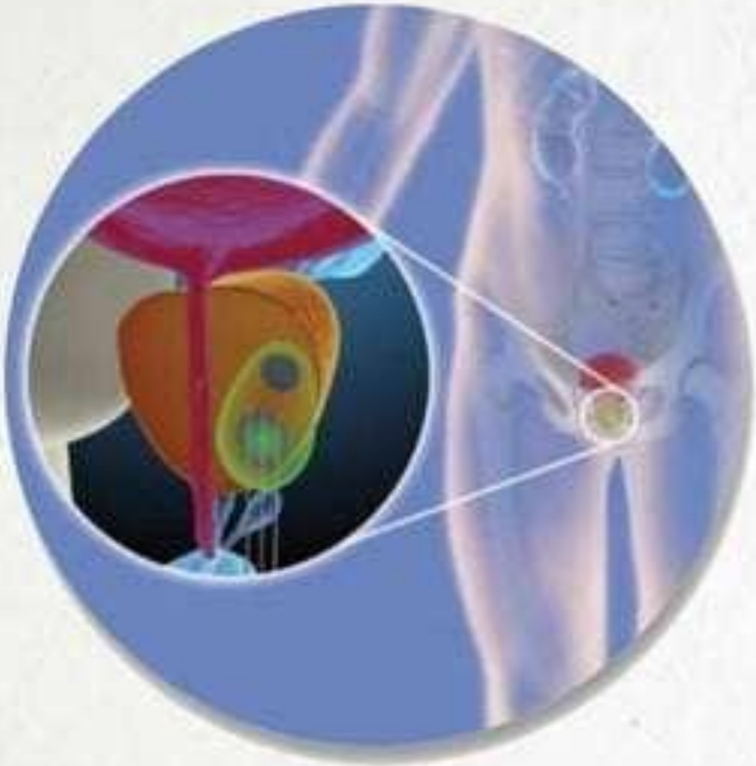
erapy?

- from the Greek word βραχυς brachys, meaning "**short-distance**".
- Also known as **internal radiotherapy, sealed source radiotherapy**, **curietherapy** or

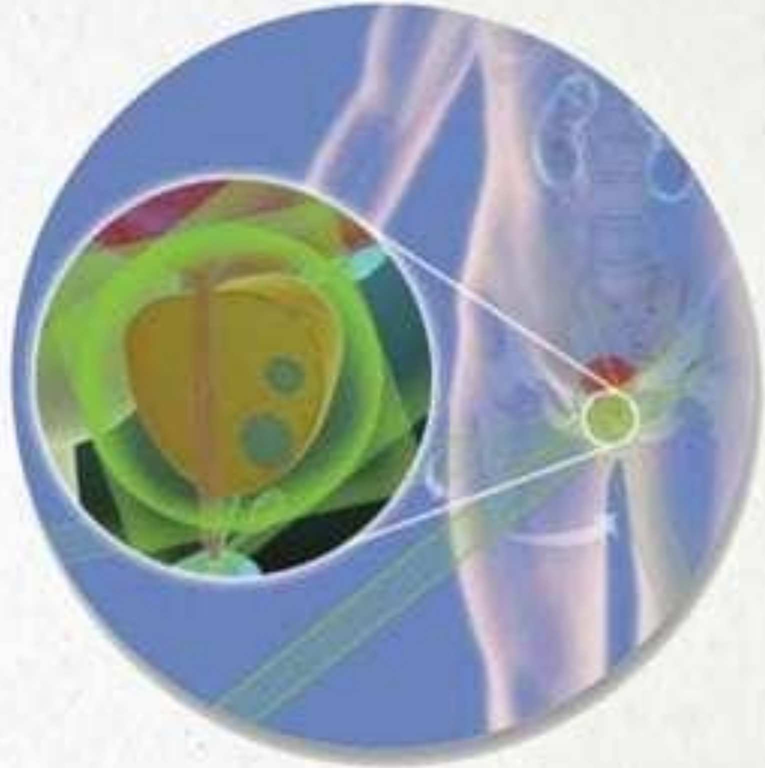
endocurietherapy.

- A type of radiation therapy used to treat cancer, involving the placement of a radioactive material, either **temporarily** or **permanently**, **directly inside the body**.

- Unlike EBRT which delivers an external radiation source through healthy tissue **(‘from the outside, in’),** brachytherapy delivers the radioactive dose directly within or adjacent to the tumor **(‘from the inside, out’).**



Brachytherapy works 'from the inside, out'



External beam radiotherapy (EBRT)
works 'from the outside, in'

- The theory behind brachytherapy is to deliver low-intensity radiation over an extended period to a relatively small volume of tissue.
- The low intensity isotopes are placed directly into a tissue or cavity depositing radiation only a short distance, covering the tumor area but sparing surrounding normal tissue.

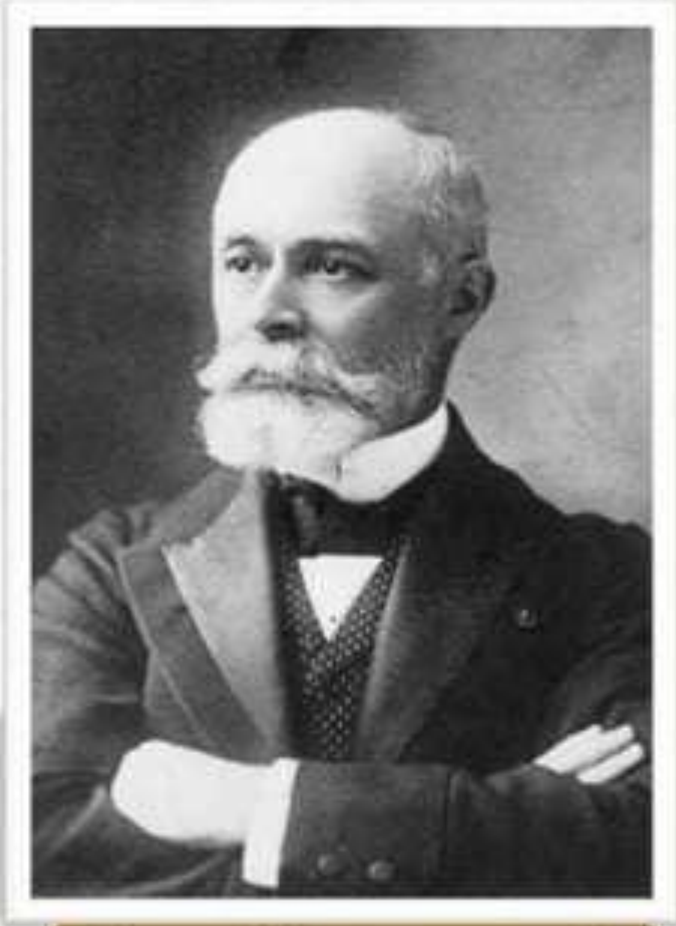
- This technique allows a higher total dose of radiation to be delivered to the tumor than is achievable with external beam radiation alone.

Historical Development

A brief timeline

1896 Discovery of radioactivity

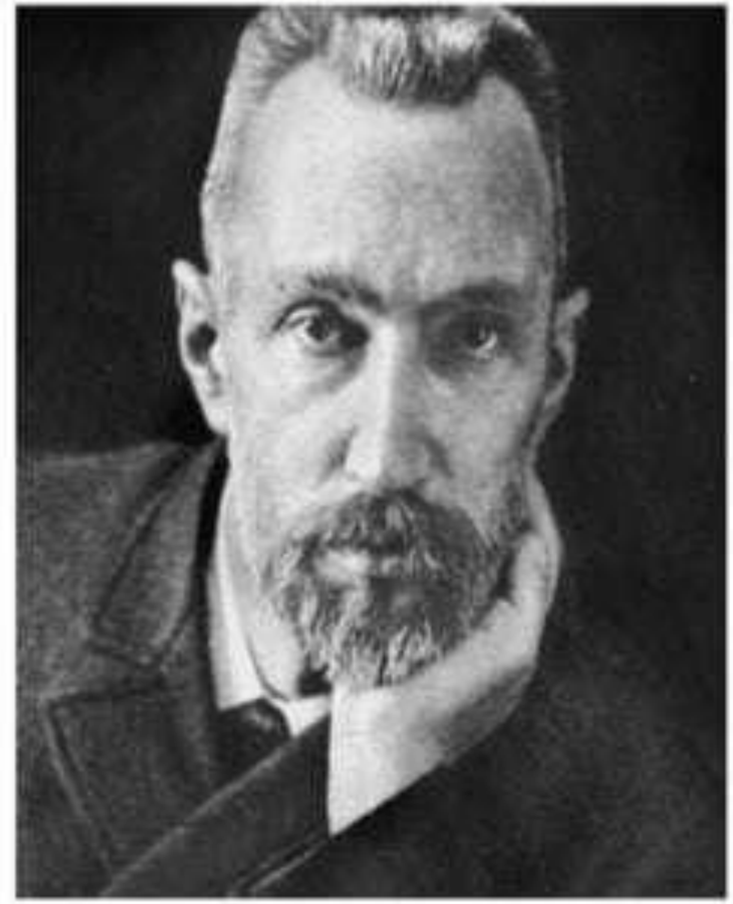
Henri Becquerel, a French physicist, accidentally discovered radioactivity. He noticed that Uranium caused a black spot to appear on a photographic plate that had not been exposed to sunlight. This discovery raised interest into the effects of radiation, which would later lead to the first use of Brachytherapy



Henri Becquerel

1901 First use of Brachytherapy

Pierre Curie (a French physicist who studied the effects of radioactivity) suggested to Henri-Alexander Danlos (a French doctor) that radioactivity could be use to treat cancer. Danlos tested the idea and found that radiation caused cancer tumors to shrink. Early techniques of brachytherapy were pioneered at the Curie Institute in Paris by Danlos and at St. Luke's and Memorial Hospital in New York by a surgeon called Robert Abbe.



Pierre Curie

1903-1950 Early pioneers

In the years after the first use of brachytherapy, a number of doctors pioneered the application of it to treat different types of cancer. These included Margaret Cleaves in the field of cervical cancer, Hugh Hampton Young and Benjamin Barringer in the field of prostate cancer and Geoffrey Keynes in the field of breast cancer.

Margaret Cleaves

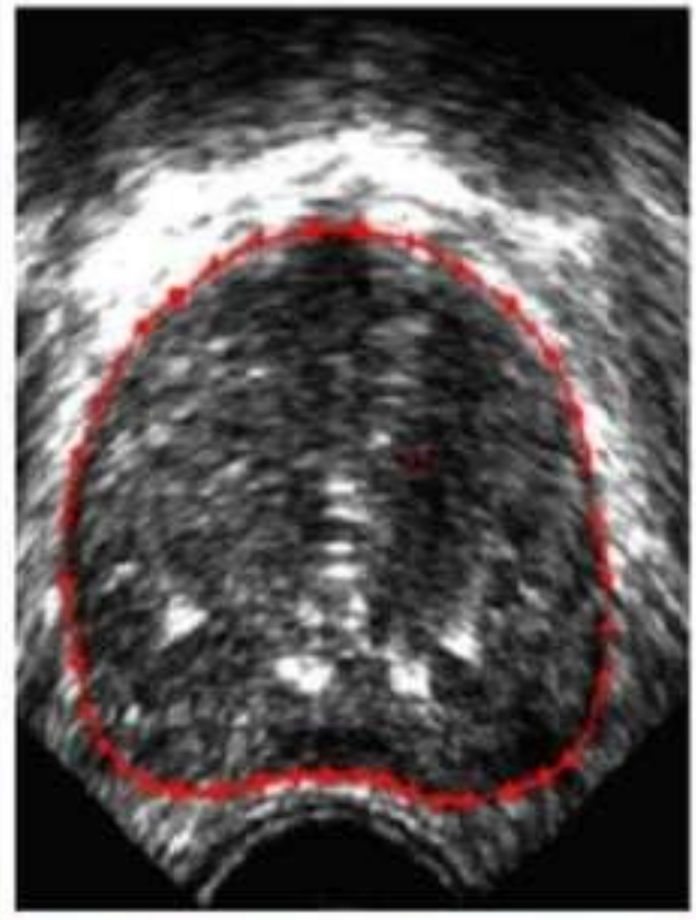
1970 Enhanced radiation safety

One of the early challenges of brachytherapy is ensuring the healthcare professionals delivering treatment were not exposed to radiation on a daily basis. By 1970's, special machine known as 'afterloaders' were made available. Afterloaders contain the radiation sources used for high dose rate brachytherapy. Staff can remotely control the 'afterloader' from a separate observation room to deliver the radiation from the machine into the patient's body.

A modern afterloader machine

1990 Advanced Imaging techniques

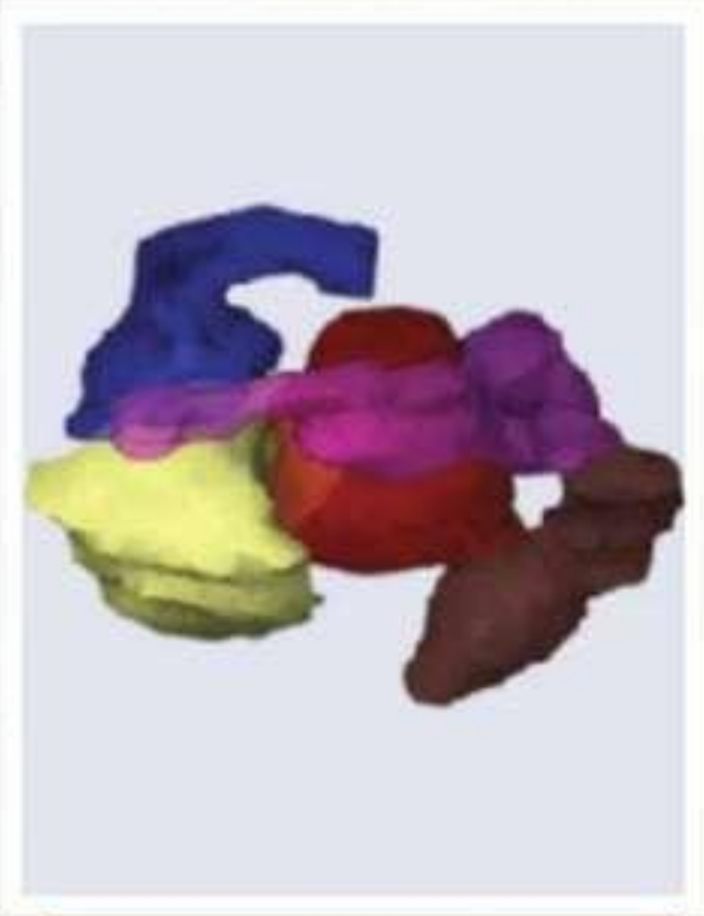
In the 1990s, various imaging technologies, such as ultrasound, magnetic resonance imaging (MRI) and computed tomography (CT) scans become more widely available. These technologies help doctors plan the brachytherapy procedures. They can also be used during the brachytherapy procedure to ensure the radiation is precisely delivered to exactly the right place.



Ultrasound image of the prostate

2000 Virtual treatment planning introduced

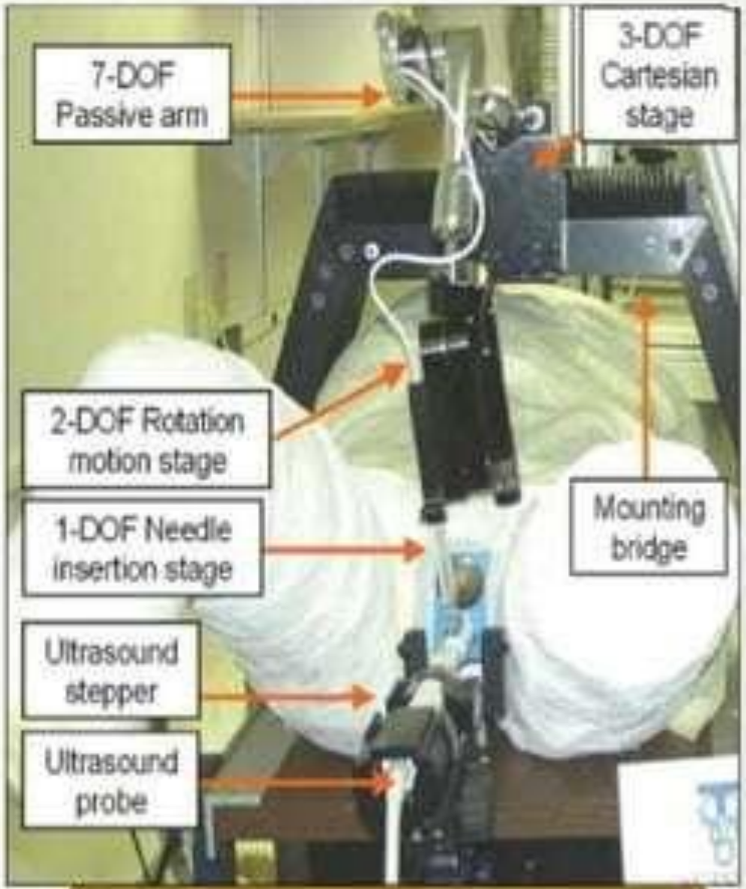
At the turn of the new century, advanced computerized brachytherapy planning systems were introduced. These enable healthcare professionals to accurately plan the delivery of the radiation using a virtual 3D representation of the patient. Doctors can then precisely target the radiation to the cancerous tumor and avoid damage to the healthy surrounding tissues.



Creation of a 3D 'virtual' patient

2005 Robotic delivery of Prostate seed therapy

The first robotic device to accurately deliver brachytherapy for prostate cancer (seed therapy) was introduced. Technological innovations such as this have helped to make brachytherapy even more effective and safe.

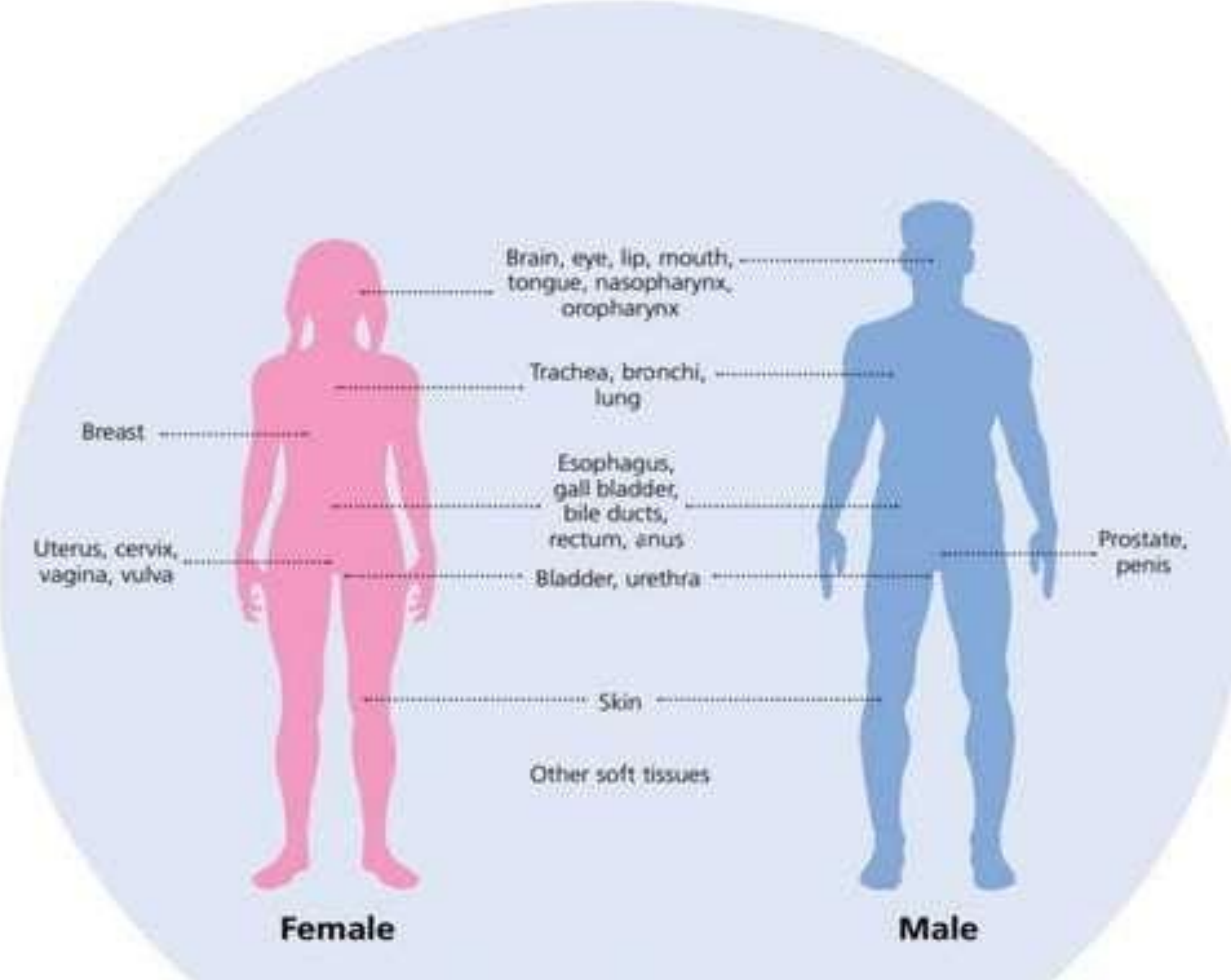


Robotic delivery of seed therapy

CLINICAL APPLICATIONS

- Brachytherapy can be used in combination with other therapies such as surgery, EBRT or chemotherapy, particularly when the tumor is too large or is not easily accessible.
- Brachytherapy has been most widely applied in the treatment of :
  - ❑ Cervical
  - ❑ Prostate
  - ❑ Breast and
  - ❑ skin cancers

Brachytherapy can also be used to treat tumors in several other body sites.



Body sites in which brachytherapy can be used to treat cancer

TYPES OF BRACHYTHERAPY

Brachytherapy can be characterized according to **three main factors**:

- **Source placement**
- **Treatment duration &**
- **Dose rate**

ACCORDING TO SOURCE PLACEMENT

- **Interstitial** - the sources are placed directly in the target tissue of the affected site, such as the prostate or breast.
- **Contact** - involves placement of the radiation source in a space next to the target tissue.
  - **Intracavitary** – A body cavity such as cervix, uterus or vagina.
  - **Intraluminal** – A body lumen such as the trachea or esophagus.
  - **Surface (Mould)** – externally such as the skin.
  - **Intravascular** – Blood vessels.

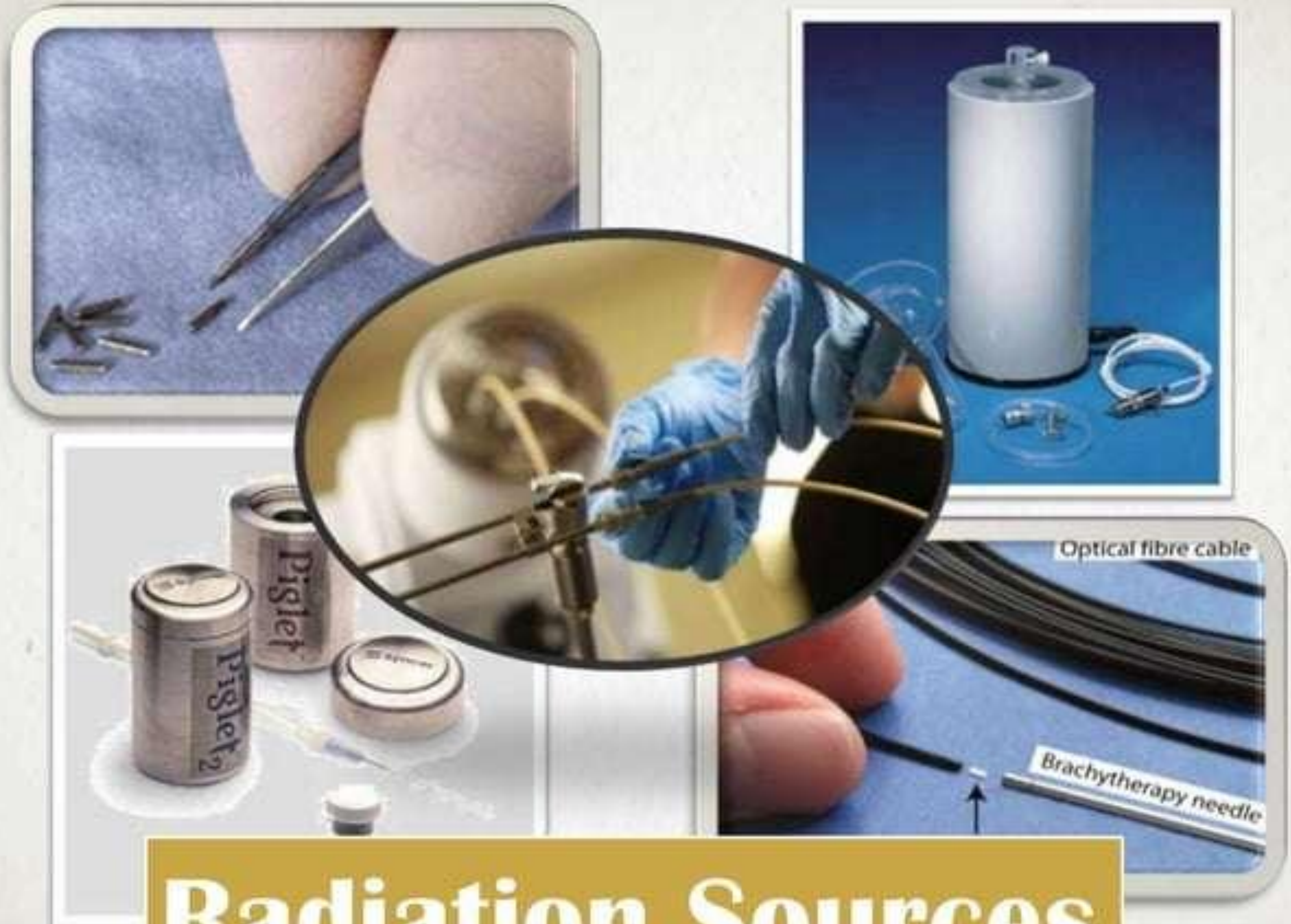
ACCORDING TO TREATMENT DURATION

- **Temporary-** Dose is delivered over a short period of time and the sources are removed after the prescribed dose has been reached. The specific treatment duration will depend on many different factors, including the required rate of dose delivery and the type, size and location of the cancer.
- **Permanent-** also known as **seed implantation**, involves placing small LDR radioactive seeds or pellets (about the size of a grain of rice) in the tumour or treatment site and leaving them there permanently to gradually decay.

ACCORDING TO DOSE RATE

- **Low-dose rate(LDR)-** Emit radiation at a rate of 0.4–2 Gy/hour. Commonly used for cancers of the oral cavity, oropharynx, sarcomas and prostate cancer
- **Medium-dose rate (MDR)-** characterized by a medium rate of dose delivery, ranging between 2-12 Gy/hour.
- **High-dose rate (HDR)-**when the rate of dose delivery **exceeds** 12 Gy/h.
- **Pulsed-dose rate (PDR)** - involves short pulses of radiation, typically once an hour, to simulate the overall rate and effectiveness of LDR treatment.

Characteristic	Type	Description	Clinical example(s)
Source Placement	Interstitial	Source place within the tumor	Breast, Prostate
	Contact	Source placed next to the tumor	Cervix, trachea, skin
Duration	Permanent	Source implanted permanently	Prostate "seed" implants
	Temporary	Source implanted for a specific treatment duration	Most brachytherapy treatments are temporary for a wide variety of cancers
Dose Rate	High	12 Gy/hour	Breast, cervix, prostate, skin
	Medium	2–12 Gy/hour	Cervix
	Low	0.4–2 Gy/hour	Prostate, oral



Radiation Sources

- In brachytherapy, the radiation dose is applied to tumor by sealed sources. The sources are implanted to the tumor tissue itself or in its close vicinity.
- They are enclosed in a protective capsule or wire which **allows the ionizing radiation to escape to treat and kill surrounding tissue**, but **prevents the charge of radioisotope** from moving or dissolving in body fluids.
- Sources can be tubes, needles, wires, pellets or seeds.

- Brachytherapy sources are usually encapsulated; the capsule serves several purposes:
    - **Containing the radioactivity;**
    - **Providing source rigidity;**
    - **Absorbing any alpha and, for photon emitting sources, beta radiation produced through the source decay.**

- The choice of an appropriate photon emitting radionuclide for a specific brachytherapy treatment depends on several relevant physical and dosimetric characteristics, the most important of which are the:

  - **Photon energies and photon beam penetration into tissue and the shielding materials;**
  - **Half-life;**
  - **Half-value layer (HVL) in shielding materials such as lead;**
  - **Specific activity;**
  - **Source strength;**
  - **Inverse square fall-off of dose with distance from the source (this is the dominant dosimetric effect, because of the very short treatment distances used in brachytherapy).**

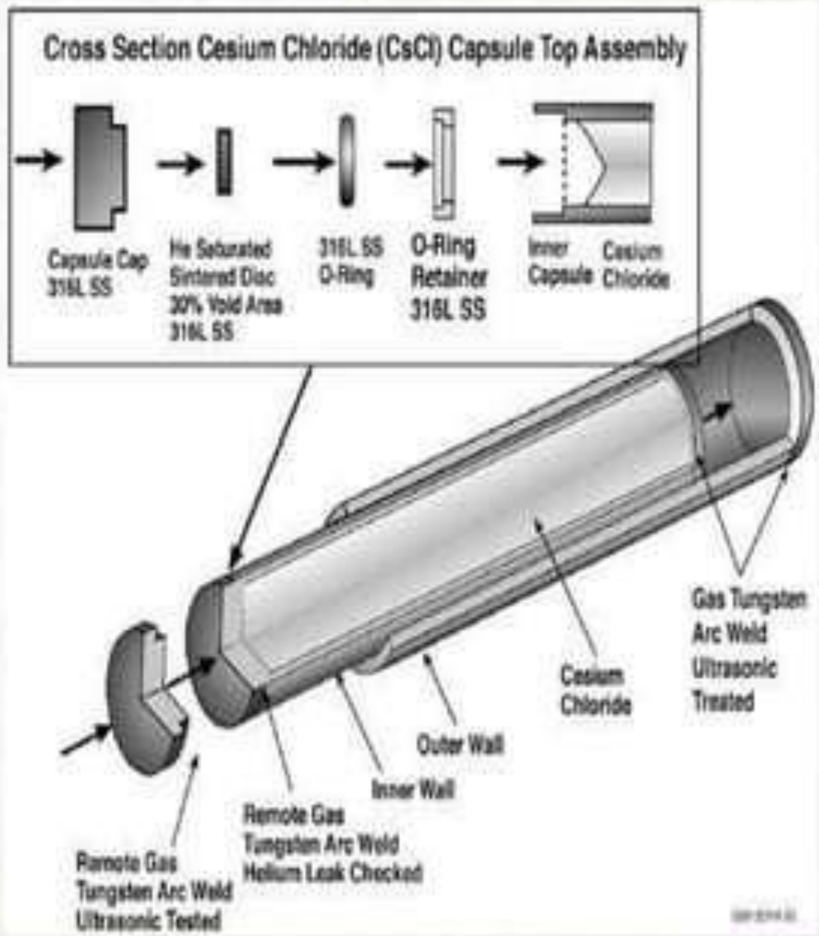
RADIATION SOURCES:

Radionuclide	Type	Half-Life	Energy
Cesium-137 (^{137}Cs)	γ-ray	30.17 years	0.662 MeV
Cobalt-60 (^{60}Co)	γ-rays	5.26 years	1.17, 1.33 MeV
Iridium-192 (^{192}Ir)	γ-rays	73.8 days	0.38 MeV (mean)
Iodine-125 (^{125}I)	γ-rays	59.6 days	27.4, 31.4 and 35.5 keV
Palladium-103 (^{103}Pd)	γ-ray	17.0 days	21 keV (mean)
Ruthenium-106 (^{106}Ru)	β^--particles	1.02 years	3.54 MeV

Commonly used radiation sources (radionuclides) for brachytherapy

CESIUM 137

- **Symbol:** (^{137}Cs)
  - **Half-Life:** 30.17 years
  - **Energy:** 0.662 MeV
  - most widely used source for the treatment of gynecological cancer
  - distributed within an insoluble glass or ceramic matrix
  - encapsulated in stainless-steel sheaths with wall thicknesses of 0.5 to 1.0 mm, active lengths of 13.5 to 15 mm, diameters of 2.6 to 3.1 mm, and total lengths of about 20 mm.



COBALT 60

- **Symbol:** (^{60}Co)
- **Half-Life:** 5.26 years
- **Energy:** 1.17-1.33 MeV
- In the form of wire which is encapsulated in a sheath of platinum, iridium or stainless steel.
- available as pellets with a typical activity of 18.5 GBq (0.5 Ci) per pellet.

IRIDIUM 192

- **Symbol:** (^{192}Ir)
  - **Half-Life:** 30.17 years
- **Energy:** 73.8 days
- available in the form of seeds, 0.5 mm in diameter and 3 mm long, for **LDR BT**
- Also used in the form of a wire (**0.3-mm or 0.6-mm outer diameter)** consisting of an iridium-platinum radioactive core encased in a 0.1-mm sheath of platinum.

IODINE 125

- **Symbol:** (^{125}I)
- **Half-Life:** 59.6 days
- **Energy:** 35.5 keV
- Used for permanent implants
- Only available as seeds. They are usually inserted into the tumour volume using special delivery 'guns'.

Source storage and handling

- Radioactive sources must be under the control of an appropriate person at all times…
  - Ordering
  - Receiving
  - Storage
  - Handling
  - Use
  - Disposal

SOURCE STORAGE

Source stores must:

- provide protection against environmental conditions
- be only for radioactive materials
- provide sufficient shielding
- be resistant to fire
- be secure
- be labelled

ACCOUNTABILITY OF SOURCES

Source accountancy records should contain:

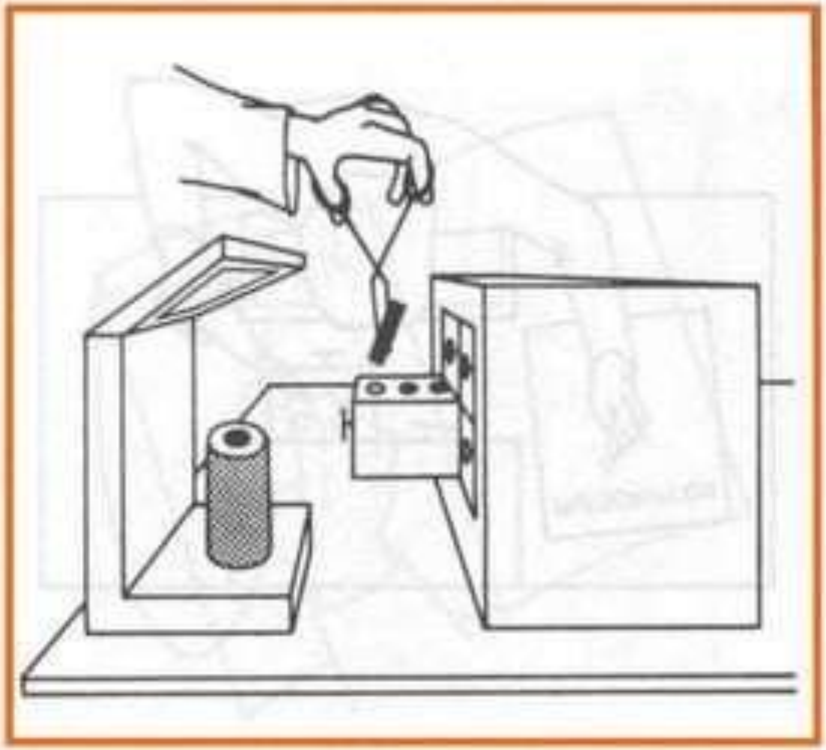
- radionuclide and activity of sources
- location and description of sources
- disposal details

The records should be updated regularly, and the location of the sources checked.

FEATURES OF SOURCE STORAGE

- Secure (lock and key)
- Labels
- Different compartments
- Shielding
- Easy access
- Well organized

TRANSFERRING SOURCES FROM AND INTO A SAFE



- Use of tweezers
- Behind shielding
- Short transport ways

HANDLING OF SOURCES

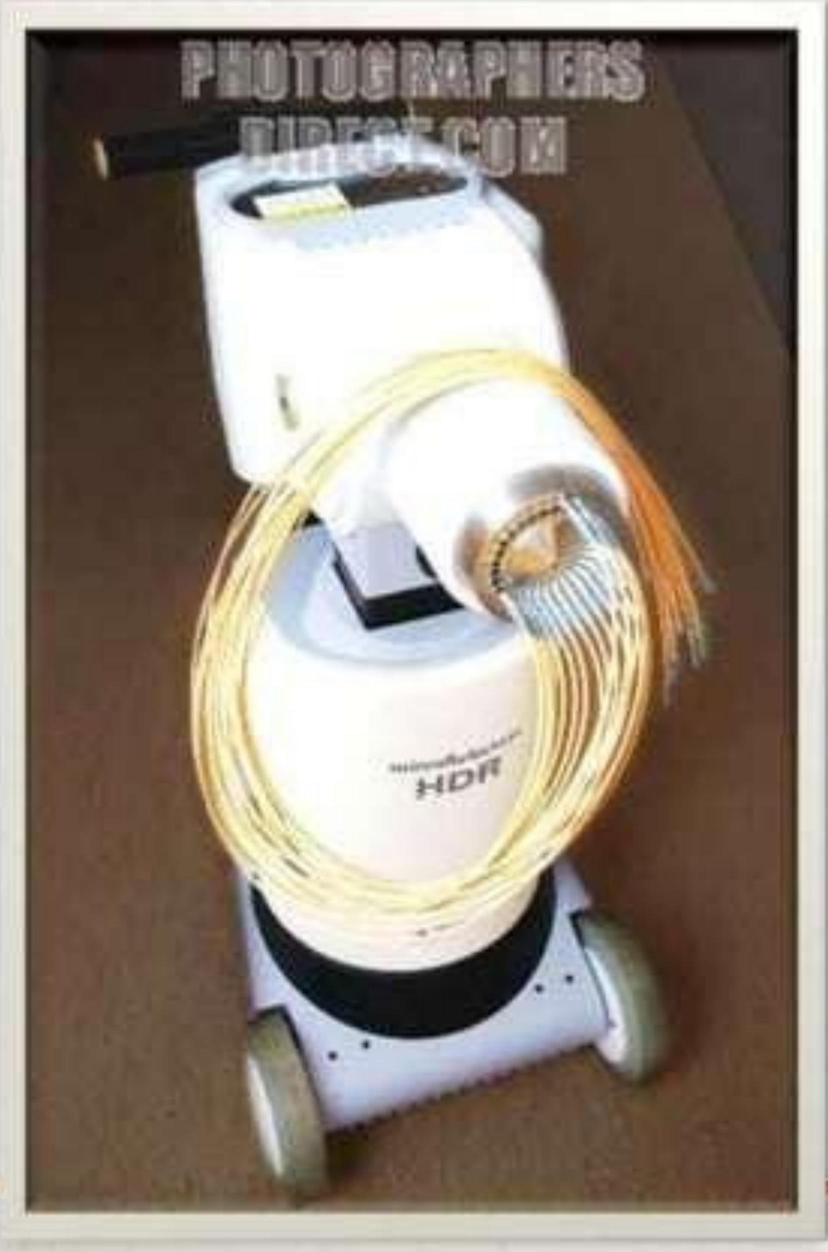
- General:
  - avoid contamination
  - use gloves
  - no eating/drinking in room
  - use long forceps

- Let someone know if you work with radioactivity

EQUIPMENTS

AFTERLOADER MACHINE

- A computerized medical device that drives a small radioactive source through catheters to predetermined dwell positions for a specific time in a patient's body during brachytherapy.


PHOTOGRAPHERS
DIRECT.COM
HDR

microSelectron

Figure 2.2 (a) One of the first remote afterloading devices for treatment of gynaecological tumours: the Curietron prototype, 1965.

Figure 2.2 (b) The new design Curietron (Courtesy BEBIG)

APPLICATOR

- A device used to hold a radioactive source in place during brachytherapy.
- Applicators are non-radioactive and are typically needles or plastic catheters. The specific type of applicator used will depend on the type of cancer being treated and the characteristics of the target tumor.

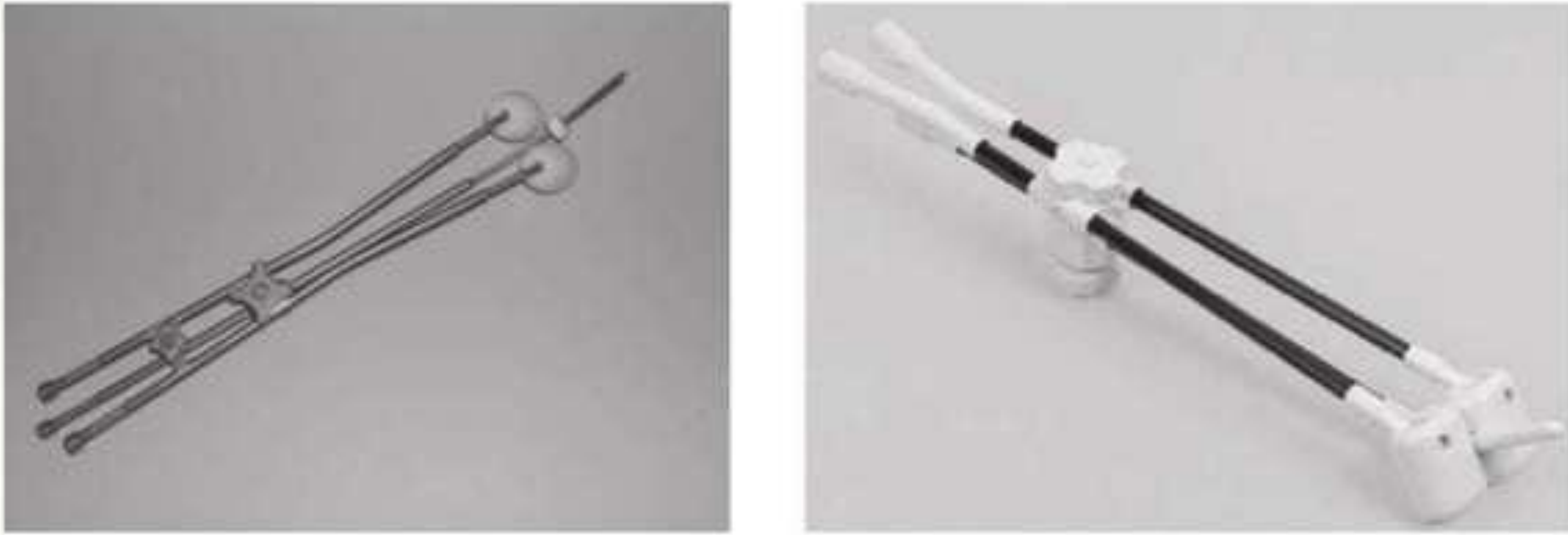
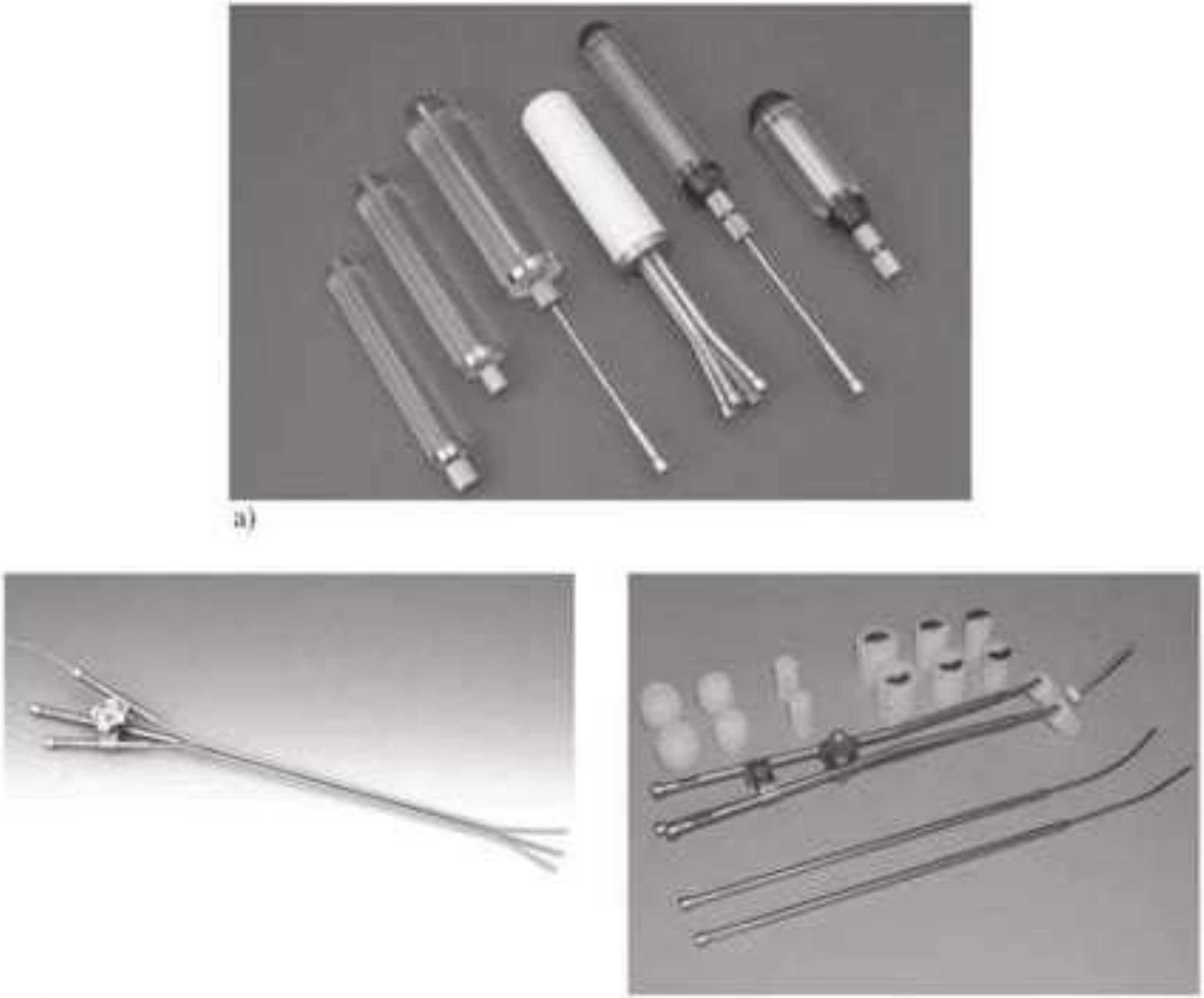


Figure 2.14 Examples of a set of CT and MR compatible gynaecological applicators, for cervical, endometrial and vaginal cancer treatment. Materials used are titanium and carbon fibres. (Courtesy Varian, Nucletron)



a) b) c)

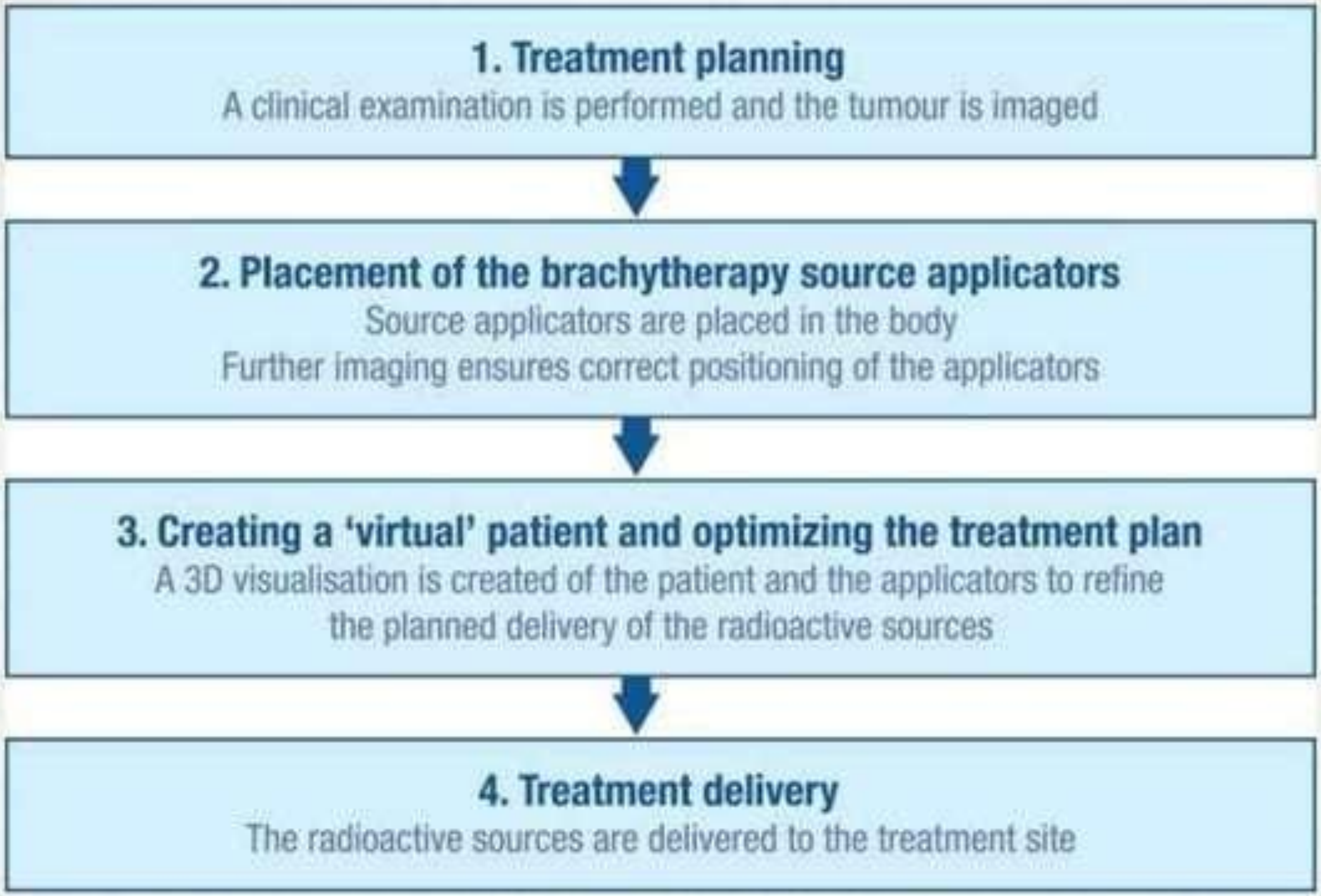
Figure 2.3 Examples of applicators for connection to afterloading equipment. (a) Vaginal cylinders. (b) Applicators for endometrial treatments. (c) A set of Fletcher-Suit-Delclos applicators with tandem and ovoids, with and without shielding. (Courtesy Varian)

:sophagus Bougie Set CT Compatible
ntended for: HDR intraluminal brachytherapy of the esophagus

CT Compatible / MR Compatibility: Conditional
tended for: HDR or PDR intracavitary brachytherapy of the endometrium
MR

Figure 7.A.1 Vaginal stump applicator and additional equipment used for endovaginal afterloading with Ir-192 HDR.

PROCEDURE



Typical stages of a brachytherapy procedure.

INITIAL PLANNING

- In order to accurately plan the brachytherapy procedure, a thorough clinical examination is performed to understand the characteristics of the tumor.
- A range of imaging modalities can be used to visualize the shape and size of the tumor and its relation to surrounding tissues and organs.
- Data from many of these sources can be used to create a 3D visualization of the tumor and the surrounding tissues.

- This initial planning helps to ensure that ‘cold spots’ (**too little irradiation**) and ‘hot spots’ (**too much irradiation**) are avoided during treatment, as these can respectively result in treatment failure and side-effects.

INSERTION AND IMAGING OF THE APPLICATOR(S)

- Before radioactive sources can be delivered to the tumor site, the applicators have to be inserted and correctly positioned in line with the initial planning.
- Imaging techniques, such as **x-ray**, **fluoroscopy** and **ultrasound** are typically used to help guide the placement of the applicators to their correct positions and to further refine the treatment plan.
- **CAT scans** and **MRI** can also be used.

- Once the applicators are inserted, they are held in place against the skin using sutures or adhesive tape to prevent them from moving. Once the applicators are confirmed as being in the correct position, further imaging can be performed to guide detailed treatment planning.

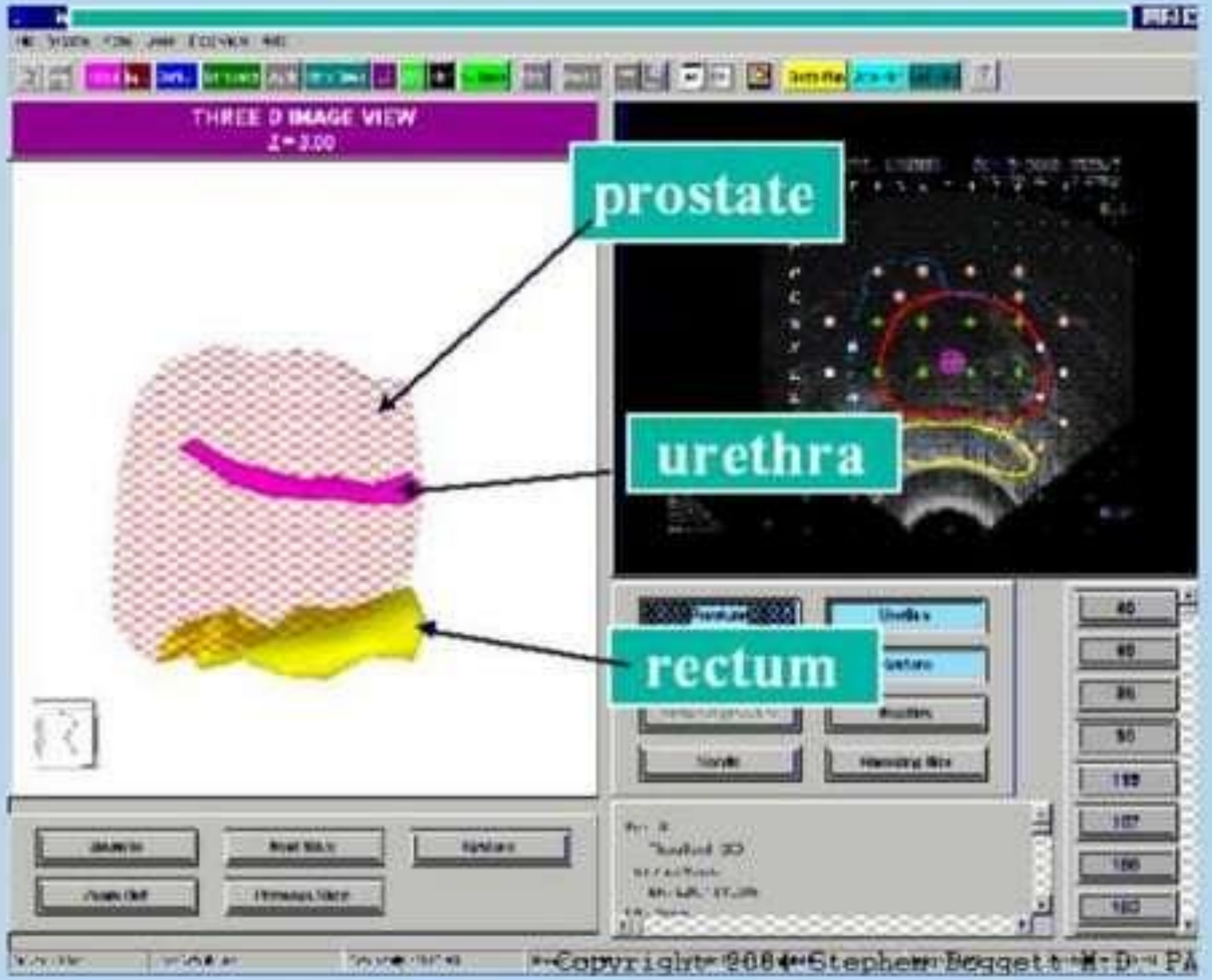
CREATION OF A VIRTUAL PATIENT

- The treatment planning software enables multiple 2D images of the treatment site to be translated into a 3D 'virtual patient', within which the position of the applicators can be defined.
- The spatial relationships between the applicators, the treatment site and the surrounding healthy tissues within this 'virtual patient' are a copy of the relationships in the actual patient.

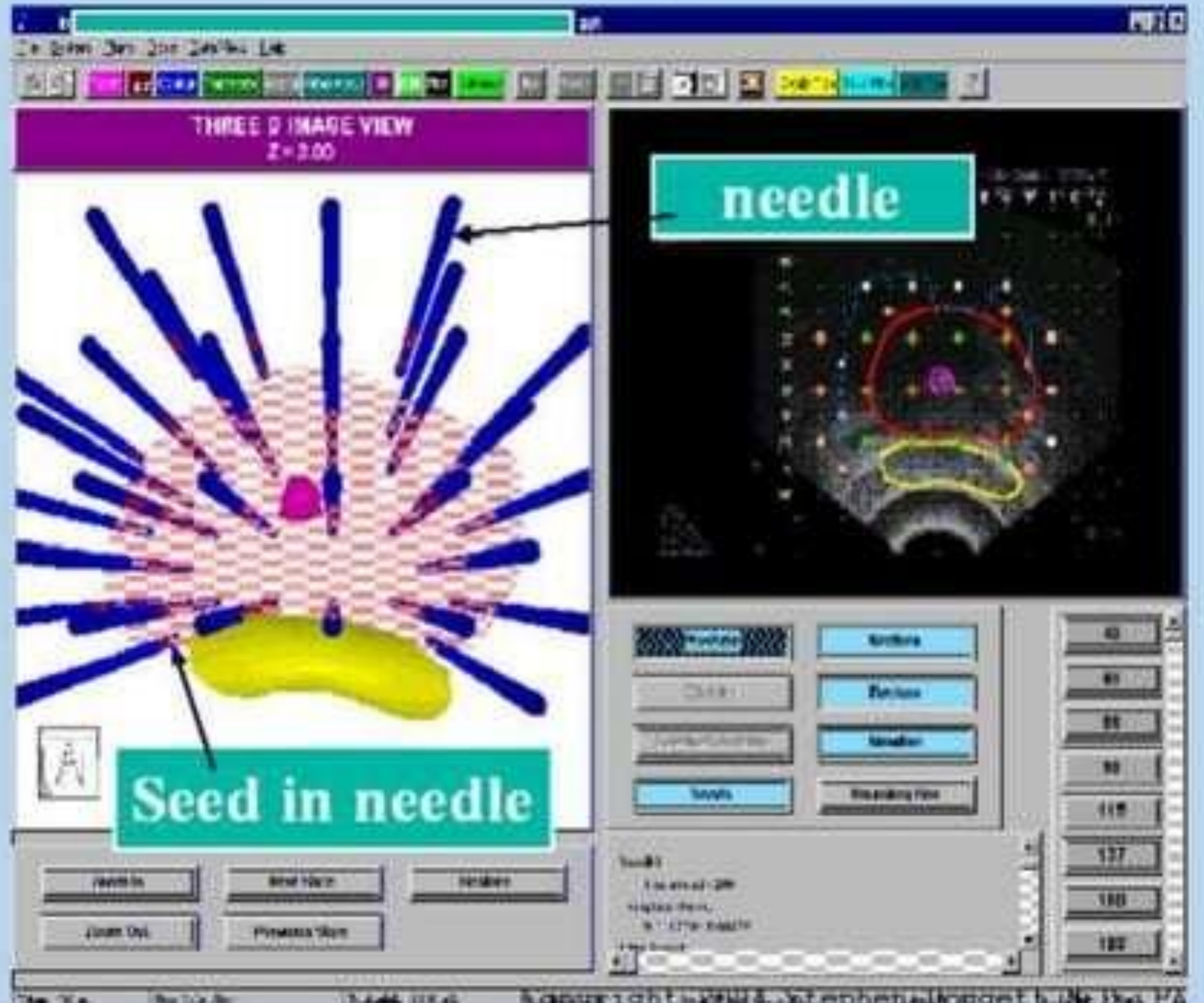
Cross section prostate ultrasound images are collected every 5 millimeters in the operating room. These images are imported into the planning system.

A light pen is used to outline the contour of the prostate, urethra and rectum on each cross sectional prostate ultrasound image.

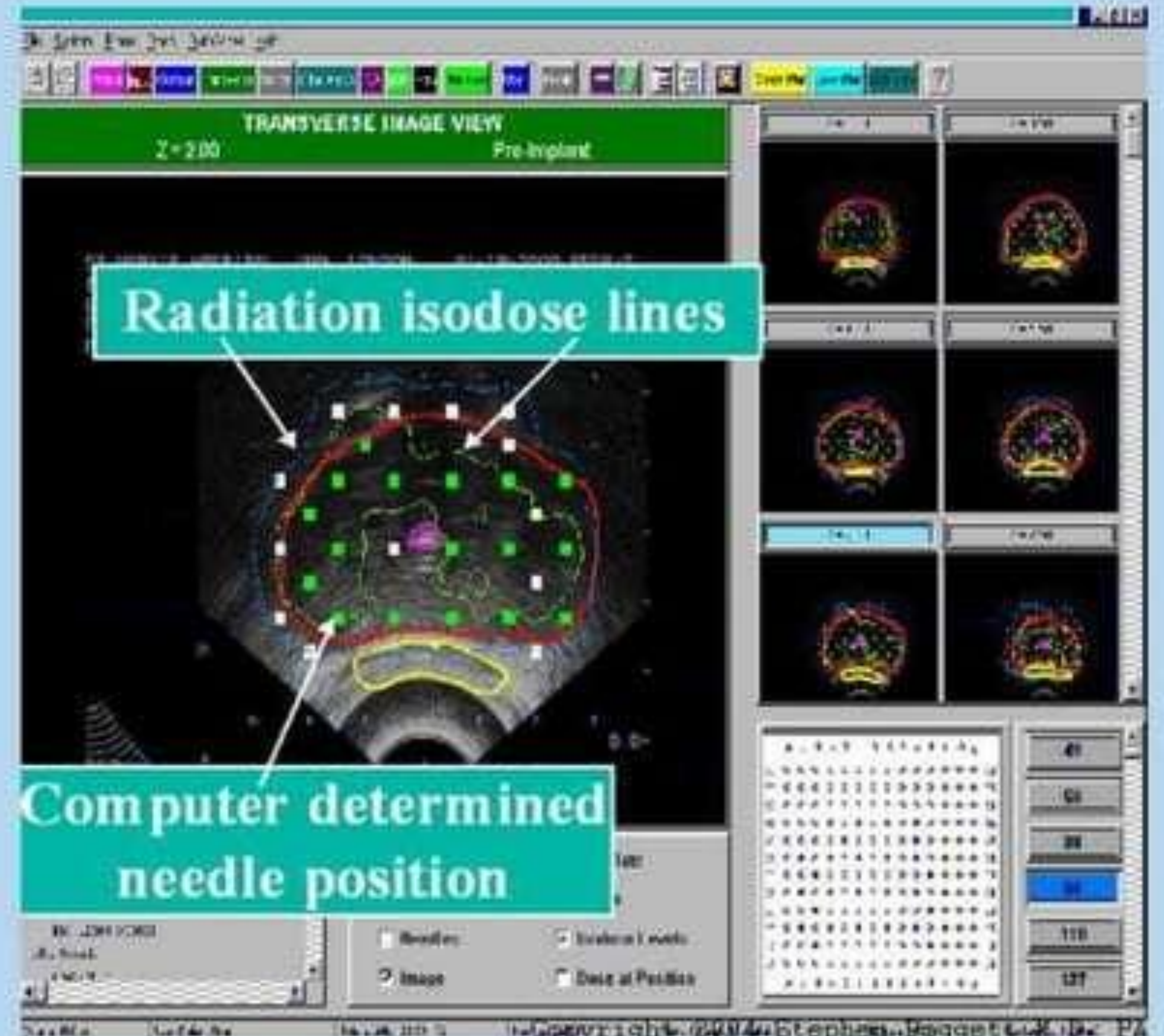
The computer creates a 3D model of the prostate, urethra and rectum that can be viewed at any angle for increased precision.



The computer specifies where in 3D each needle and each seed within those needles should be placed. The chance for human error is therefore greatly diminished.



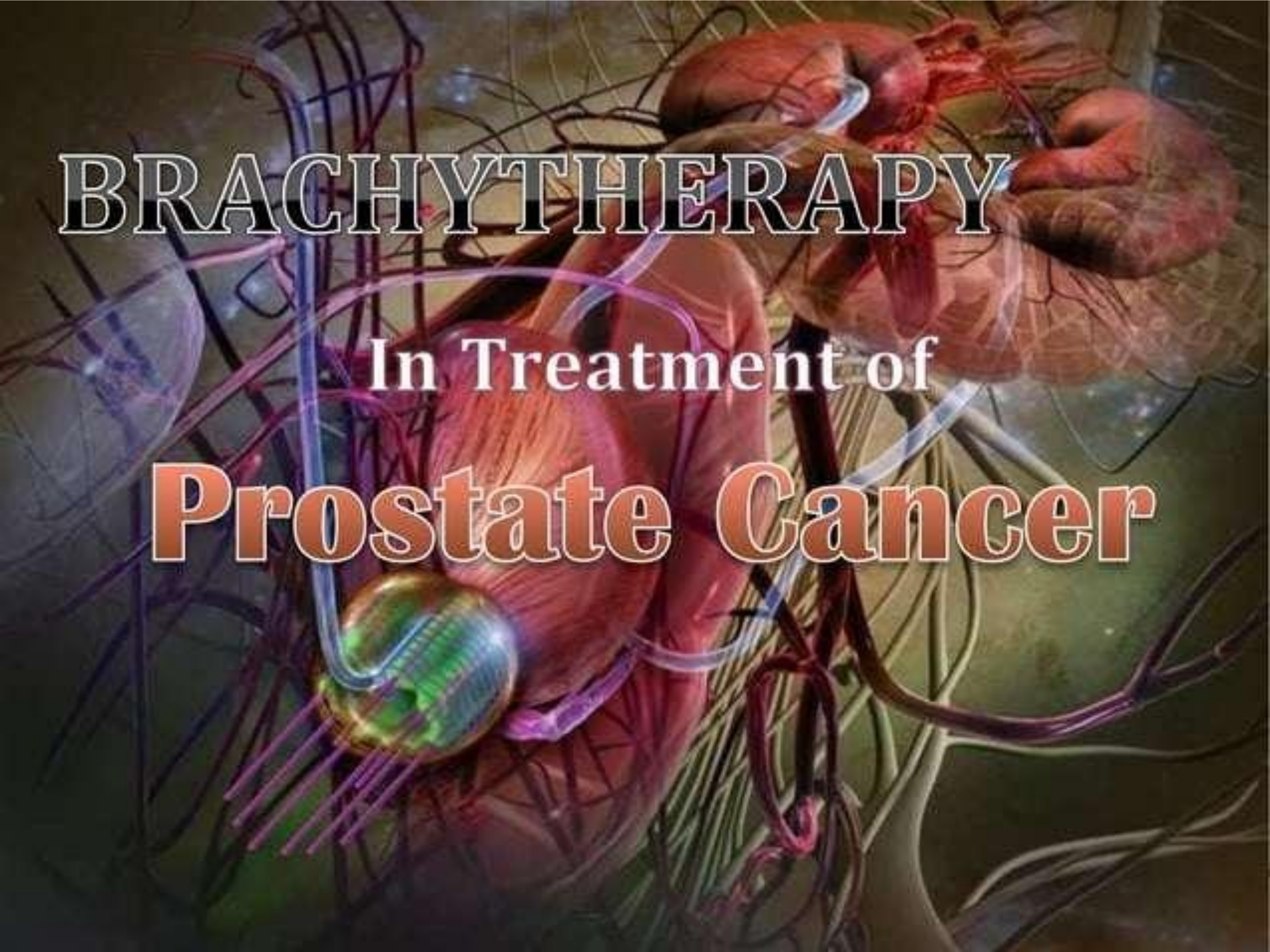
The computer has performed 3 million calculations in a few seconds, producing a precise plan determining where each needle and seed should be implanted. Minor adjustments can be made in a few seconds to fine tune the plan prior to needle placement if needed.



TREATMENT DELIVERY

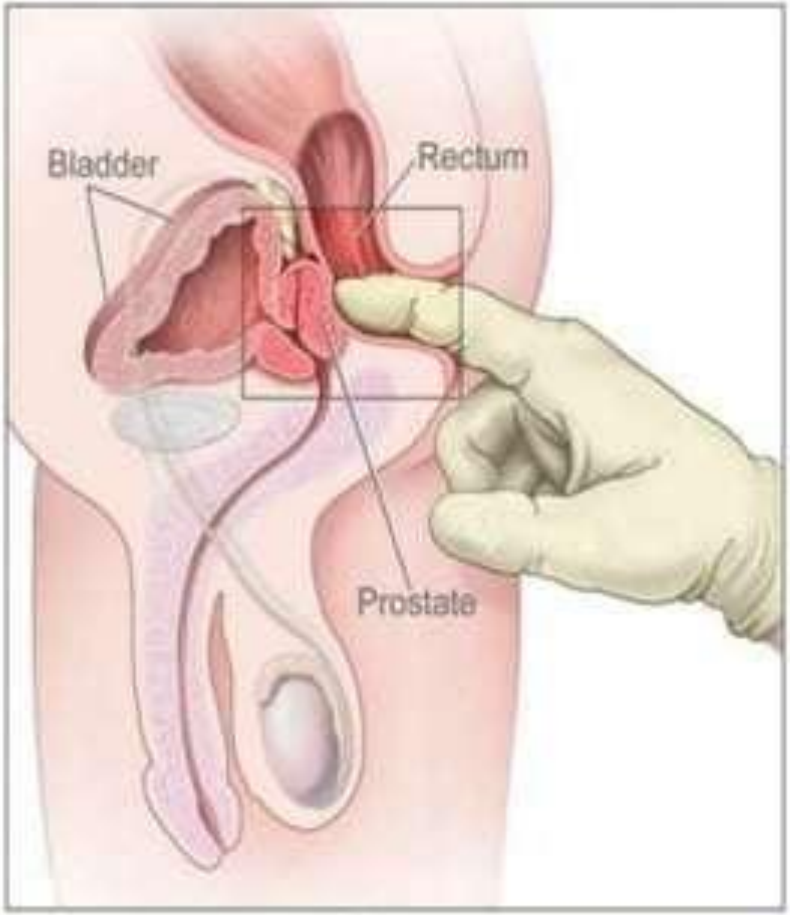
- The sources used in Brachytherapy can be delivered manually, but are more commonly delivered through a technique known as 'afterloading'.
- Manual delivery of brachytherapy is limited to a few LDR applications, due to risk of radiation exposure to clinical staff
- In contrast, afterloading **involves the accurate positioning of non-radioactive applicators in the treatment site**, which are subsequently loaded with the radiation sources. In manual afterloading, the source is delivered into the applicator by the operator

- Once the applicators are correctly positioned in the patient, they are connected to an 'afterloader' machine (containing the radioactive sources) through a series of connecting guide tubes.
- The treatment plan is sent to the afterloader, which then controls the delivery of the sources along the guide tubes into the pre-specified positions within the applicator.
- This process is only engaged once staff are removed from the treatment room.
- The sources remain in place for a pre-specified length of time, again following the treatment plan, following which they are returned along the tubes to the afterloader.


BRACHYTHERAPY
In Treatment of
Prostate Cancer

PROSTATE

- literally "**one who stands before**", "**protector**", "**guardian**"
- Tubuloalveolar exocrine gland of the male reproductive system in most mammals.
- A walnut-sized gland located between the bladder and the penis



- A healthy human prostate is classically said to be **slightly larger than a walnut**.
- The mean weight of the normal prostate in adult males is about **11 grams**, usually ranging between **7 and 16 grams**.
- It surrounds the urethra just below the urinary bladder and can be felt during a rectal exam.

FUNCTION

The function of the prostate is to secrete a slightly alkaline fluid, milky or white in appearance, that usually constitutes 50–75% of the volume of the semen along with spermatozoa and seminal vesicle fluid.

DESCRIPTION

- Brachytherapy takes 30 minutes or more, depending on the type of therapy you have. Before the procedure, you will be given medicine so that you do not feel pain. You may receive:
- A sedative to make you drowsy and numbing medicine on your perineum. This is the area between the anus and rectum.
- Anesthesia. With spinal anesthesia, you will be drowsy but awake, and numb below the waist. With general anesthesia, you will be asleep and pain-free.

After you receive anesthesia:

- The doctor places an ultrasound probe into your rectum to view the area. The probe is like a camera connected to a video monitor in the room. A catheter (tube) may be placed in your bladder to drain urine.
- The doctor uses ultrasound or a CT scan to plan and then place the seeds that deliver radiation into your prostate. The seeds are placed with needles or special applicators through your perineum.
- Placing the seeds may hurt a little (if you are awake).

Types of brachytherapy

- **Low-dose radiation brachytherapy** is the most common type of treatment. The seeds stay inside your prostate and put out a small amount of radiation for several months. You go about your normal routine with the seeds in place.
- **High-dose radiation brachytherapy** lasts about 30 minutes. Your doctor inserts the radioactive material into the prostate. The doctor may use a computerized robot to do this. The radioactive material is removed right away after treatment.

WHY THE PROCEDURE IS PERFORMED?

- Brachytherapy is often used for men with a small prostate cancer that is found early and is slow-growing. Brachytherapy has fewer complications and side effects than standard radiation therapy. You will also need fewer visits with the doctor.

BEFORE THE PROCEDURE

Tell your doctor or nurse what medicines you are taking. These include medicines, supplements, or herbs you bought without a prescription.

Before this procedure:

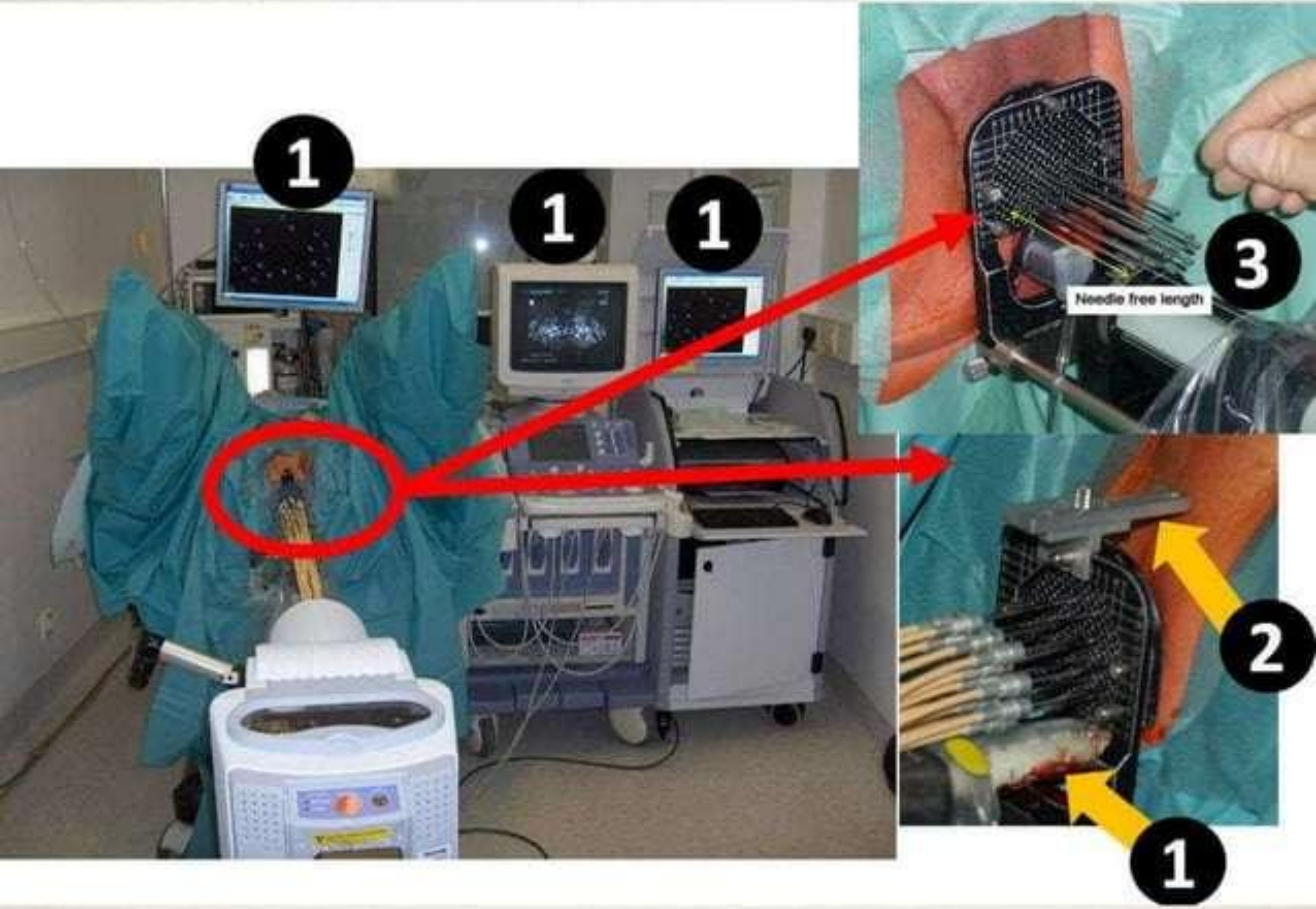
- You may need to have ultrasounds, x-rays, or CT scans to prepare for the procedure.
- Several days before the procedure, you may be told to stop taking medicines that make it hard for your blood to clot. These medicines include aspirin, ibuprofen (Advil), clopidogrel (Plavix), and warfarin (Coumadin).
- Ask your doctor which medicines you should still take on the day of the surgery.
- If you smoke, try to stop. Your doctor or nurse can help.

ON THE DAY OF THE PROCEDURE:

- You will likely be asked not to drink or eat anything for several hours before the procedure.
- Take the medicines your doctor told you to take with a small sip of water.
- Your doctor or nurse will tell you when to arrive at the hospital. Be sure to arrive on time.

AFTER THE PROCEDURE

- You may be sleepy and have mild pain and tenderness after the procedure.
- After an outpatient procedure, you can go home as soon as the anesthesia wears off. In rare cases, you will need to spend 1 - 2 days in the hospital. If you stay in the hospital, your visitors will need to follow special radiation safety precautions.
- If you have a permanent implant, your doctor may tell you to limit the amount of time you spend around children and women who are pregnant. After a few weeks to months, the radiation is gone and will not cause any harm. Because of this, there is no need to take out the seeds.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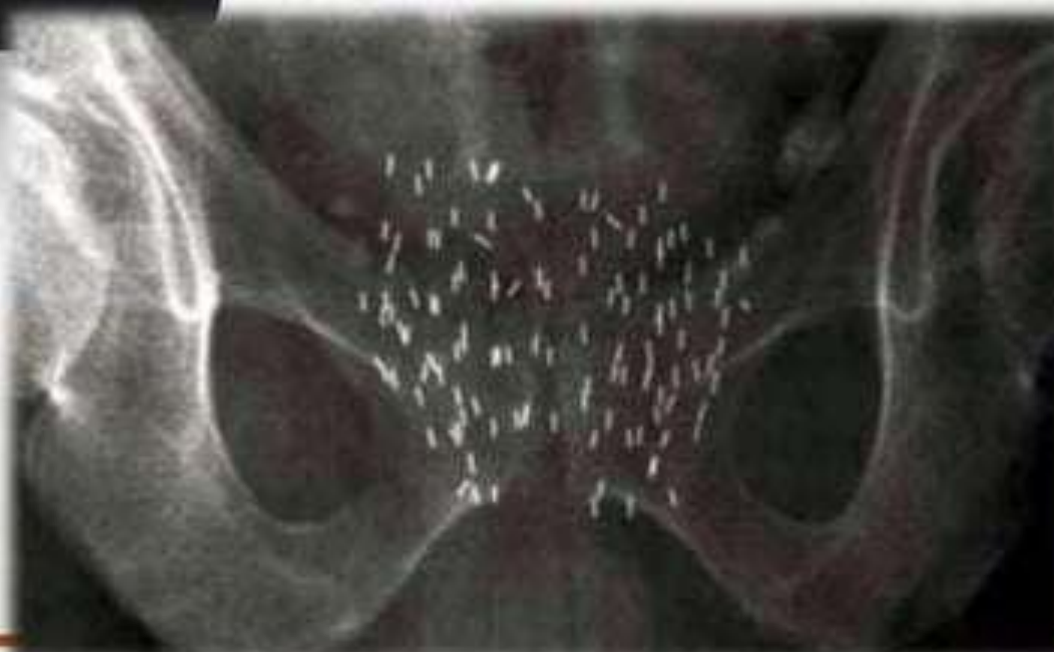

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