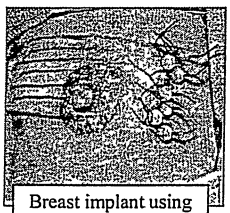
Brachytherapy

- The use of radioactive sources in close proximity to the target area for radiotherapy



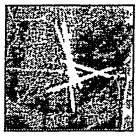
Breast implant using radioactive 192-Ir wire

X-ray of a gynaecological implant using an applicator loaded with 137-Cs sources



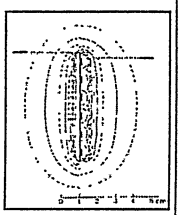
Brachytherapy overview

- Brachytherapy uses encapsulated radioactive sources to deliver a high dose to tissues near the source
- brachy (Greek) = short (distance)
- Inverse square law determines most of the dose distribution



Brachytherapy

- Characterized by strong dose gradients
- Many different techniques and sources available
- Implants are highly customized for individual patients



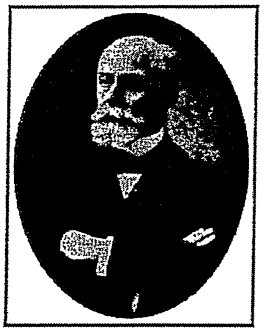
Brachytherapy

- Use of radioactive materials in direct contact with patients - more radiation safety issues than in external beam radiotherapy
- Less than 10% of radiotherapy patients are treated with brachytherpay
- Per patient treated the number of accidents in brachytherapy is considerably higher than in EBT

Objectives of part VI

- To be familiar with typical radioactive sources used in cancer treatment
- To be aware of different implant types and techniques
- To appreciate the implications of life implants vs manual and remote afterloading
- To understand the differences between low and high dose rate brachytherapy equipment
- To be familiar with some special current implant techniques (prostate seed implants, endovascular brachytherapy)

Henri Becquerel (1852-1908)



Discovered radioactivity in 1896

1. Sealed sources



- IAEA BSS glossary: "Radioactive material that is a) permanently sealed in a capsule or b) closely bound and in a solid form."
- In other words: the activity is fixed to its carrier and contamination of the environment is not possible as long as the source is intact

Sealed sources

- Have an activity which can be derived from a calibration certificate and the half life of the isotope (nothing is lost)
- MUST be checked for integrity regularly - a good means of doing this is by wipe tests

Sealed and unsealed sources in radiotherapy

- Both are used to treat cancer
- Sealed sources are used for brachytherapy - they are discussed here
- Unsealed sources may be used for systemic treatments - they are discussed in more detail in the course on Nuclear Medicine

Some examples for unsealed source radiotherapy

- 131-I for thyroid treatment
- 89-Sr and 153-Sm for treatment of bone metastasis
- 32-P for hematological cancers

Note

- All brachytherapy sources are of an activity which makes them of 'regulatory concern'
- Therefore, persons ordering, receiving, handling, storing and disposing them must have appropriate training and hold the appropriate license.

2. The ideal source in brachytherapy



What do you think one would expect from and ideal brachytherapy source?

Clinical usefulness determined by

- **Half life** = the time after which half of the original activity is still present in the source
- **Specific activity** = activity per gram of material. The higher the smaller a source of a particular activity can be made
- **Radiation energy** determines the range of radiation in tissue (AND the requirements for shielding)

The Ideal Brachytherapy source

- Pure gamma emitter - betas or alphas are too short in range and result in very high doses to small volumes around the source
- Medium gamma energy
  - high enough to treat the target with homogenous dose
  - low enough to avoid normal tissues and reduce shielding requirements
- High specific activity
  - suitable also for high dose rate applications
  - small

The Ideal Brachytherapy source

- Stable daughter product
- For temporary implants: long half life
  - allows economical re-use of sources
- For permanent implants: medi... half life

The ideal source does not exist, however we can get close

3. Real brachytherapy Sources

- A variety of source types and isotopes are currently in use
- They differ for different applications because of
  - half life,
  - size (specific activity) and
  - radiation energy
- When deciding on a source one must also keep the shielding requirements in mind.

Brachytherapy Sources

Radionuclide	Half-life	Photon Energy (MeV)	Half-value Layer (mm lead)
^{226}Ra	1600 years	0.047 - 2.45 (0.83 ave)	8.0
^{222}Rn	3.83 days	0.047 - 2.45 (0.83 ave)	8.0
^{60}Co	5.26 years	1.17, 1.33	11.0
^{137}Cs	30.0 years	0.662	5.5
^{192}Ir	74.2 days	0.136 - 1.06 (0.38 ave)	2.5
^{198}Au	2.7 days	0.412	2.5
^{125}I	60.2 days	0.028 ave	0.025
^{103}Pd	17.0 days	0.021 ave	0.008

Brachytherapy source types (ICRU report 58)

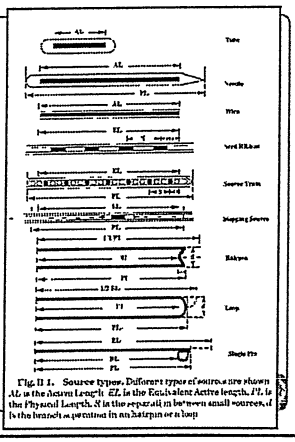
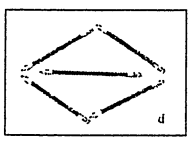


Fig. II 1. Source types. Different types of source are shown. AL is the Active Length. EL is the Equivalent Active length. PL is the Physical Length. If in the case of a hairpin or a loop

Brachytherapy sources

- The first isotope used clinically was radium around 1903
- However, radium and radon have only historical importance - they should not be used in a modern radiotherapy department





Brachytherapy sources

- However, radium and radon have only historical importance - they should not be used in a modern radiotherapy department
- Because:
  - wide energy spectrum leading to high dose close to the source and still high dose around the patient - shielding difficult
  - Radon, the daughter product of radium, is a noble gas which is very difficult to contain - contamination risk
  - The long half life means disposal is very difficult

Popular sources: 137-Cs

- "Cesium 137"
- Main substitute for radium
- Mostly used in gynecological applications
- Long half life of 30 years ---> decay correction necessary every 6 months
- Sources are expensive and must be replaced every 10 to 15 years

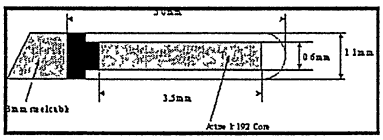
Popular sources: 192-Ir

- "Iridium 192"
- Many different forms available
- Most important source for HDR applications
- Medium half life (75 days) - decay correction necessary for each treatment
- Needs to be replaced every 3 to 4 months to maintain effective activity and therefore an acceptable treatment time

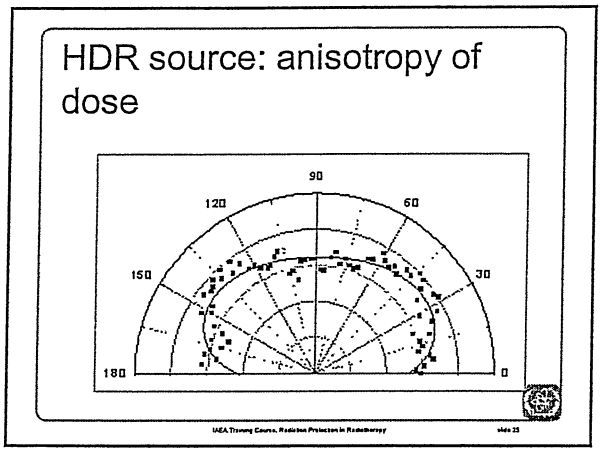
Popular sources: 192-Ir

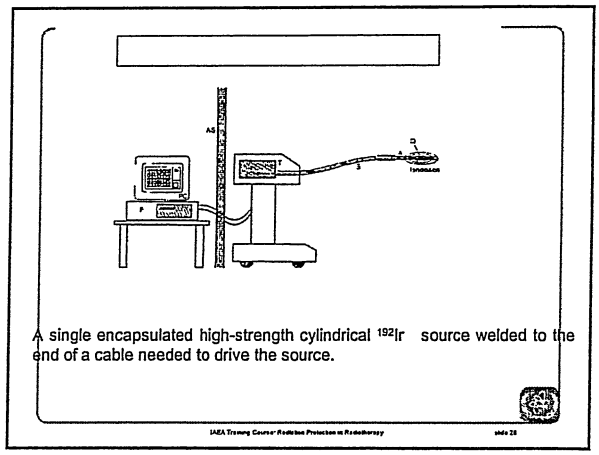
- "Iridium 192"
- High specific activity - therefore even high activity sources can be miniaturized essential for HDR applications
- A bit easier to shield than 137-Cs - because the gamma energies of 192-Ir range from 136 to 1062keV (effective energy around 350keV)

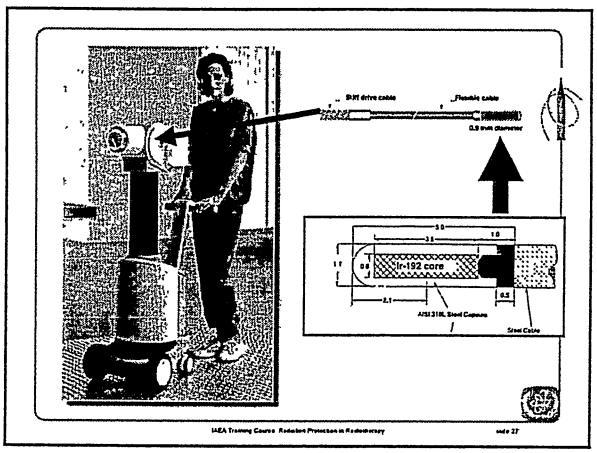
HDR 192-Ir source

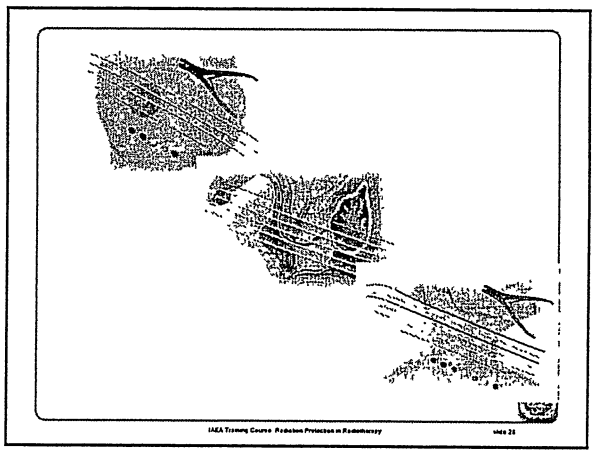


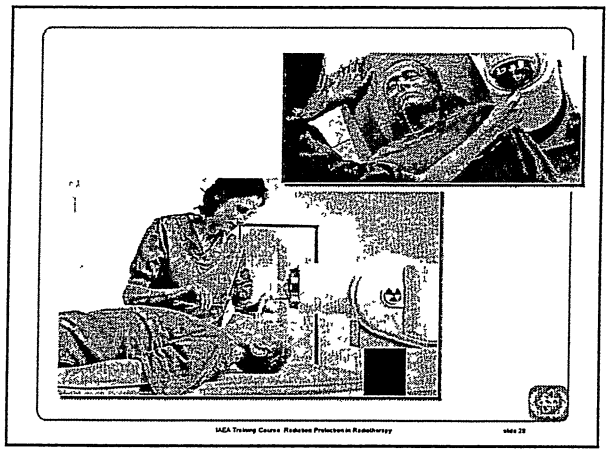
- 10 Ci (370GBq)
- diameter of the order of 1mm
- length of the order of 10mm
- dual encapsulation
- attached to steel cable

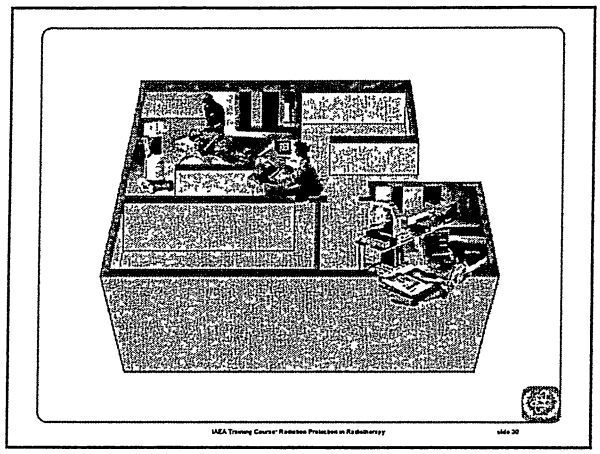

HDR source: anisotropy of dose
90
120
60
150
30
180
0

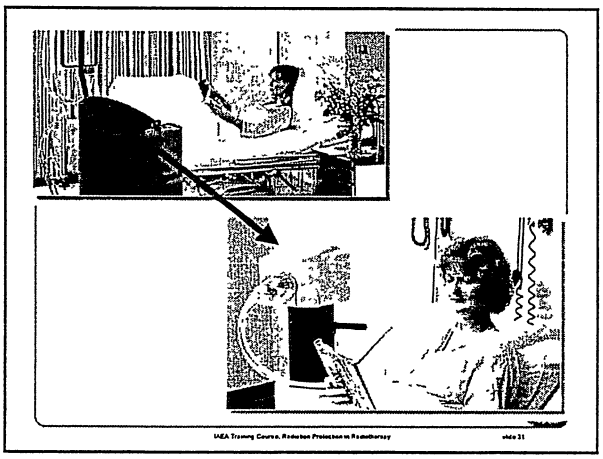

A single encapsulated high-strength cylindrical 192Ir source welded to the end of a cable needed to drive the source.

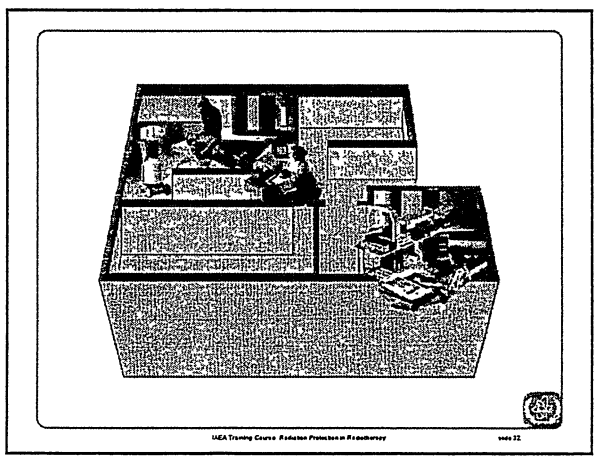


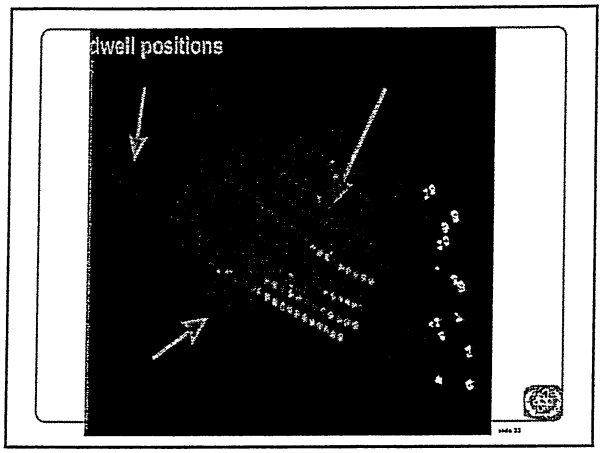


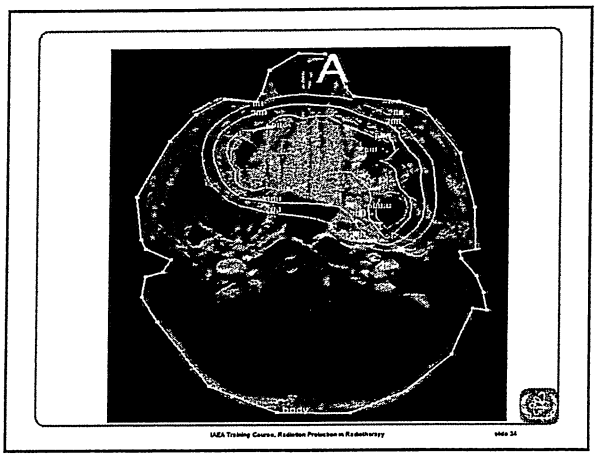






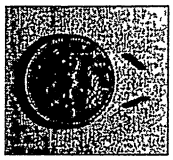






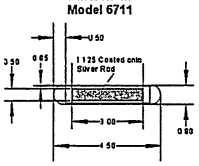
Popular sources: 125-I

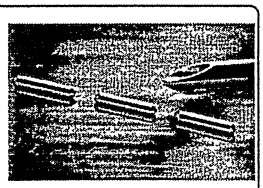
- Very low energy - therefore shielding is easy and radiation from an implant is easily absorbed in the patient: permanent implants are possible
- Mostly used in the form of seeds



125-I seeds

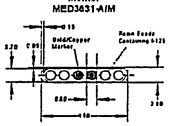
Amersham
Model 6711



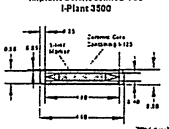


- Many different designs

Mentor
MED3631-A/M

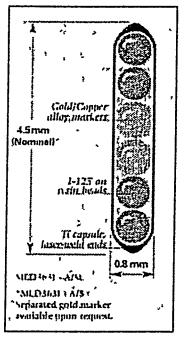


Implant Sciences/Med-Tec
I-Plant 3500



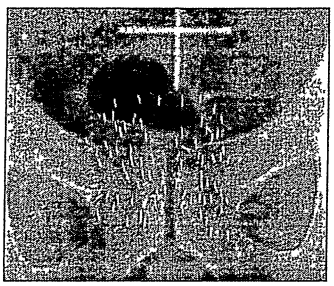
125-I seeds

- Design aims and features:
  - sealed source
  - non-toxic tissue compatible encapsulation
  - isotropic dose distribution
  - radio-opaque for localization



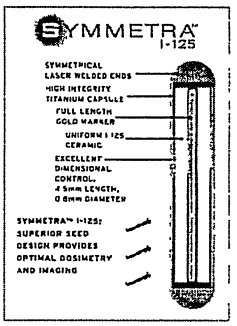
Mentor

X-ray visibility of 125-I seeds



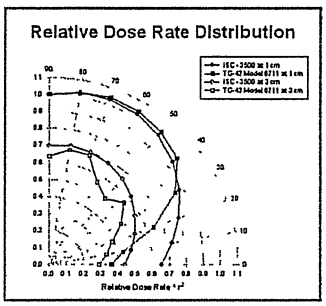
125-I seeds

- A different design:
  - radio-opaque for X-ray visualization
  - MRI compatibility desirable
  - No contamination



A source example

Symmetry of dose distribution



Other isotopes used for seeds

- Palladium 103
  - Half Life = 17 days - dose rate about 2.5 times larger than for 125-I
  - Energy = 22 keV
  - TVL lead = 0.05mm
- Gold 198
  - Half Life = 2.7 days - short enough to let activity decay in the patient
  - Energy = 412 keV
  - TVL lead = around 8mm

Brachytherapy Sources

- A variety of source shapes and forms:
  - pellets = balls of approximately 3 mm diameter
  - seeds = small cylinders about 1 mm diameter and 4 mm length
  - needles = between 15 and 45 mm active length
  - tubes = about 14 mm length, used for gynaecological implants
  - hairpins = shaped as 'hairpins', approximately 60 mm active length
  - wire = any length, usually customised in the hospital - inactive ends may be added
  - HDR sources = high activity miniature cylinder sources approximately 1mm diameter, 10mm length

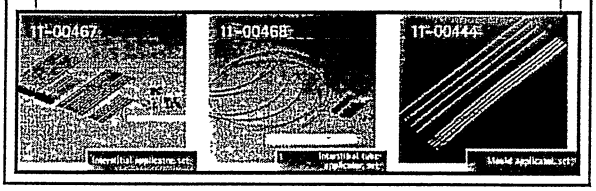
Source form examples



- Seeds (discussed before):
  - small containers for activity
  - usually 125-I, 103-Pd or 198-Au for permanent implant such as prostate cancer
- Needles and hairpins:
  - for 'life' implants in the operating theatre - activity is directly introduced in the target region of the patient
  - usually 192-Ir for temporary implants eg. of the tongue

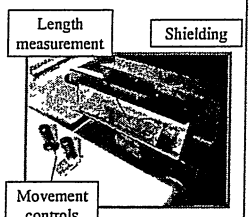
Source form: 192-Ir wire

- Used for LDR interstitial implants
- Cut to appropriate length prior to implant to suit individual patient
- Cutting using manual technique or cutter...



Source form 192-Ir wires

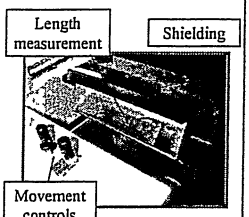
- 192-Ir wire:
  - activity between 0.5 and 10mCi per cm
  - used for interstitial implants
  - low to medium dose rate
  - can be cut from 50 cm long coils to the desired length for a particular patient



Source form example

- 192-Ir wire:
  - activity between 0.5 and 10mCi per cm
  - coils to the desired length for a particular patient

Cut wire is strictly speaking not a sealed source



The requirements of BSS:

Appendix IV.8. "Registrants and licensees, in specific co-operation with suppliers, shall ensure that the following responsibilities be discharged, if applicable:

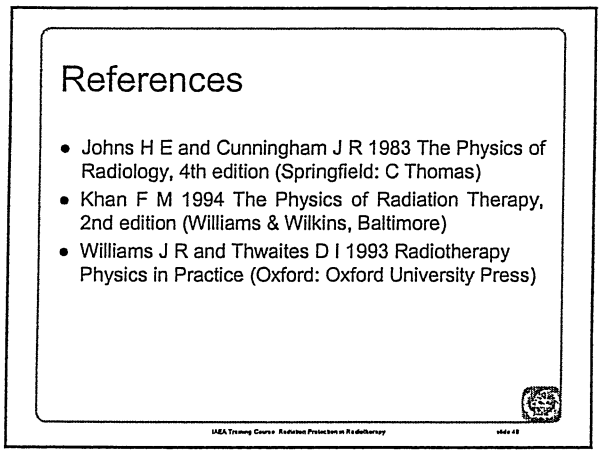
(a) to provide a well designed and constructed source that:
  (i) provides for protection and safety in compliance with the Standards;
  (ii) meets engineering, performance and functional specifications; and
  (iii) meets quality norms commensurate with the protection and safety significance of components and systems;

(b) to ensure that sources be tested to demonstrate compliance with the appropriate specifications; and

(c) to make available information in a major world language acceptable to the user concerning the proper installation and use of the source and its associated risks."

Summary

- A wide variety of radioactive sources have been used for brachytherapy in many different physical forms
- The most common sources are 137-Cs, 192-Ir and 125-I
- Regular check of source integrity is essential to ensure the source can be classified as 'sealed'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• Khan F M 1994 The Physics of Radiation Therapy, 2nd edition (Williams & Wilkins, Baltimore)
• Williams J R and Thwaites D I 1993 Radiotherapy Physics in Practice (Oxford: Oxford University Press)