Radiation Protection in Brachytherapy in the Next Decade

SESSION 4

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RADIATION PROTECTION IN MEDICINE
Setting the Scene for the Next Decade
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IAEA - WHO

Radiation Protection in Brachytherapy

- CASE FOR BRACHYTHERAPY
- PATIENT CONSIDERATIONS
- STAFF CONSIDERATIONS
- PUBLIC CONSIDERATIONS
- CONCLUSIONS

Radiation Protection in Brachytherapy

CASE FOR BRACHYTHERAPY

Worldwide Cancer Rates Continue to Rise

- 7.6 Million (13%) deaths in 2008 (WHO).
- Lung, stomach, liver, colon, breast, cervical …
- ~70% of all cancer deaths in 2008 were in low- and middle-income countries.
- Cancer expected to continue to rise up to ~26.4 Million cases (IARC), 13.1 Million deaths in 2030.
- Radiotherapy plays an important role in cancer management.
- Advances of last 10 y shifting goals from life preservation to cure with increased quality of life.

Brachytherapy Advantages

Placing a radiation source internally, either into or immediately next to the tumor, or externally on the tumor.

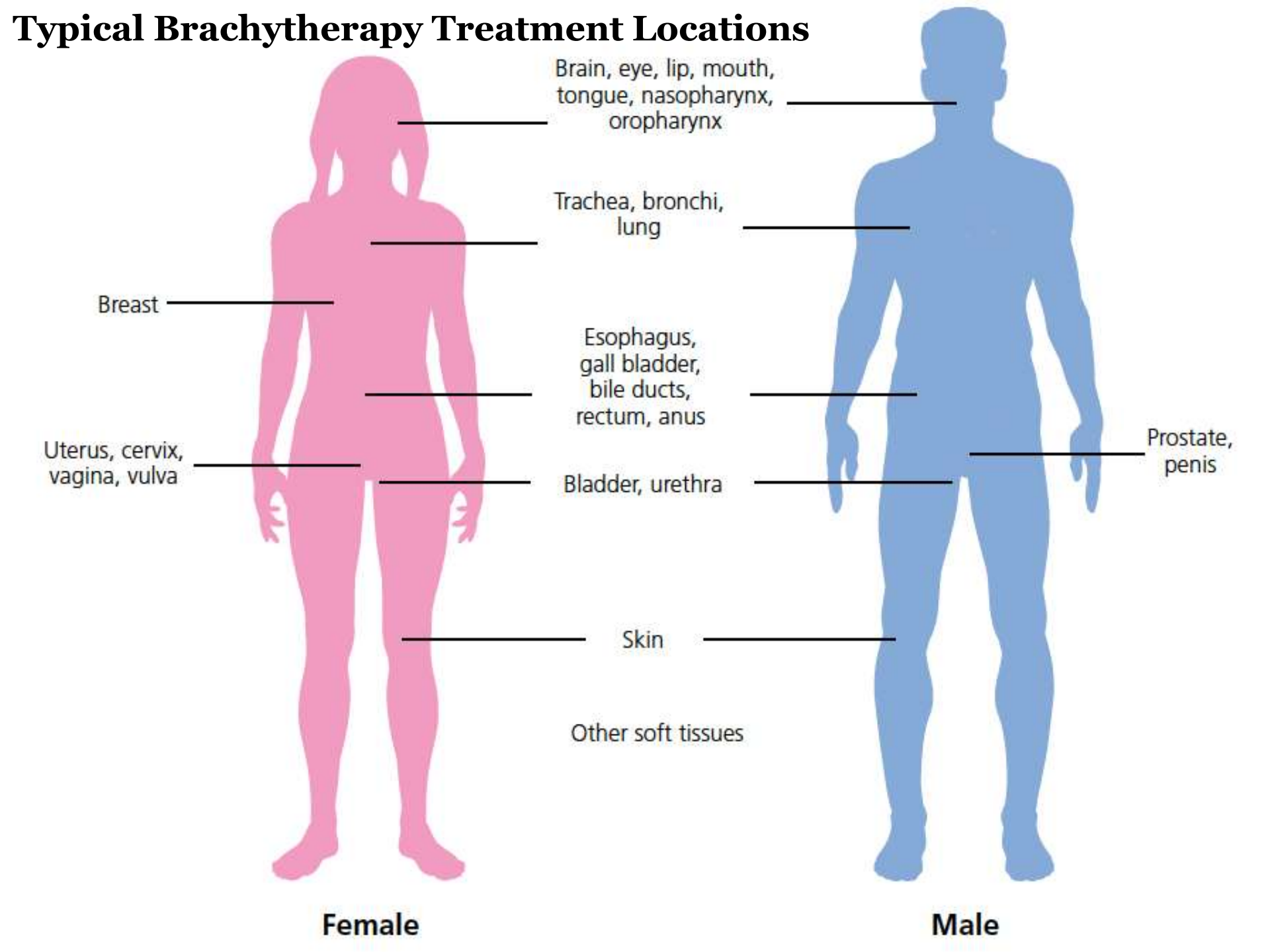
100+ year history.

14,000+ publications

in the last 50 y.

- Precision – delivery of highly targeted, individualized dose.
- Conformity – targeted, shaped dose.
- Efficacy – cure rates comparable to surgery and EBRT, and enhanced in combination.
- Optimized – effective tumor dose with sparing of surrounding tissue, reduced side effects/toxicity/2nd Ca.
- Shorter Times – of ~1-5 d.
- Cost Effective – < $, outpatient.

Typical Brachytherapy Treatment Locations



Worldwide Brachytherapy Pattern of Use

- >400,000 treatments in 2007 (UNSCEAR).
- >500,000 HDR alone now (ICRP).
- 50% increase in patients per center in some regions.
- >0.12 treatments per 1,000 population.
- Gynecological > Genitourinary > Prostate > Breast > Head and Neck > Others.
- US – >90% cervical Ca with EBRT + brachytherapy.
- Palliative care needed in 50% of inoperable Ca cases.
- Growth over the last decade. (see Guedea's work).
- Appropriateness Criteria would support *increases*.

Infrastructure Needs for Next Decade

- + Studies of Current Patterns of Use
- + Studies of Future Patterns of Need
- + Patient access and adherence
- + Facilities
- + Innovation
- + Equipment
- + Staff
- + Training
- + Safety
- - Disparities

Radiation Protection in Brachytherapy

PATIENT CONSIDERATIONS

Brachytherapy Source Selection

Nuclide	Photon Avg MeV	Half-Life	First HVL mm lead	$\frac{\mu Gy\ m^2}{GBq\ h}$
Co-60	1.25	5.26 y	12	309
Cs-137	0.66	30.0 y	6.5	79
Au-198	0.41	2.7 d	3	55
Ir-192	0.38	73.8 d	6	116
I-125	0.028	60 d	0.02	34
Pd-103	0.021	17 d	0.01	35
Ra-226 (0.5 mm Pt)	0.83	1600 y	16	234

Alternatively –
High Energy Beta sources, e.g. P-32, Sr-90, Ru-106, etc.
Neutron sources, e.g. Cf-252

Brachytherapy Optimization

Source Placement

- Target = tumor and local surrounding.
- Applicators (catheters or needles or seeds).
- Contact or Interstitial
- Temporary – timed.
- Permanent – seeds, microspheres.

Dose Rate

- LDR – Low 0.4-2 Gy/h
  - Sources, wires, ribbons, seeds, plaques, spheres
- HDR – High > 12 Gy/h
  - Source tip, catheters
- PDR – Pulsed
  - Gynecological or head and neck

Rapid Changes in Dosimetric Approach

Pre-Treatment Planning

- 2D, radiography based
- 3D, volume based
  - CT
  - MRI
  - PET

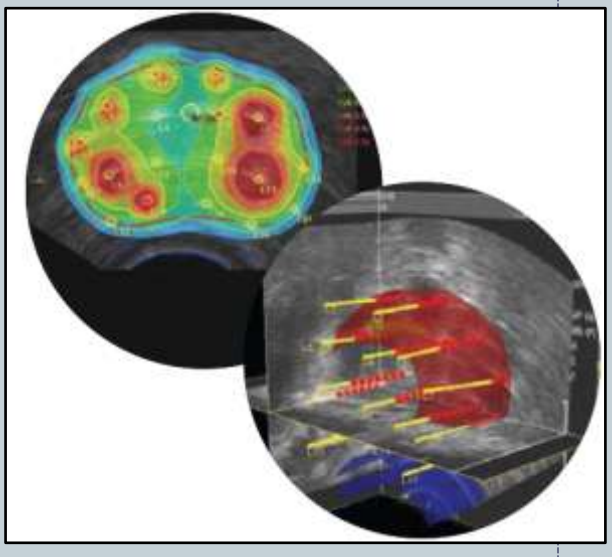


Image-Guided Real-Time

- Ultrasound.
- Fluoroscopy.*
- O-Arm CT.*
- Intraoperative optimized planning.
- 4D (3D+time) approaches.
- In-vivo dosimeters…

Accidents Happen (still?!)

Types

- HDR (~34%), rate 0.03%
  - >500 accidents and > 1 death per ICRP.
- LDR (~32%), rate 0.30%
  - notably implants
- Incorrect source strengths.
- Dose calculation errors.
- Misplacements.
- Dislodgements.

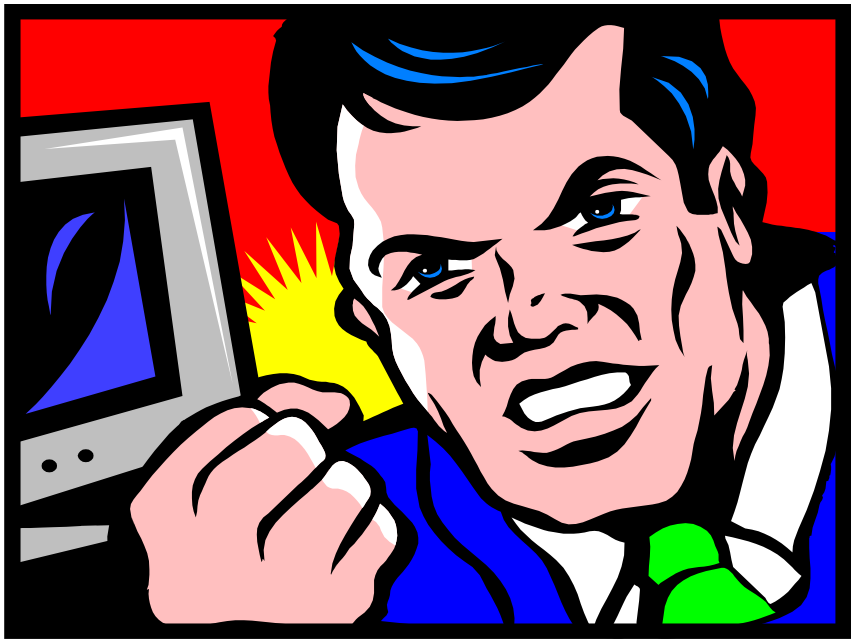
Causes?

- Human
- HDR 1.6-5 Gy/min!
- Afterloader complex technology.
- Incorrect source strength/calibration.
- Prostate visualization?
- Equipment.

When looking at Why…

First reaction is often to…

BLAME SOMEONE !



Brachytherapy Medical Error Event

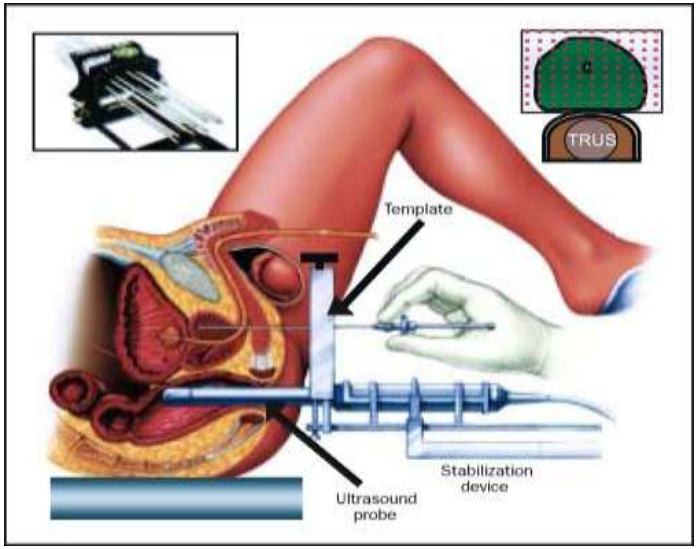
Brachytherapy Medical Error Event

Quality Management Guidelines Exist … *Implemented??*

- ICRP-97 Prevention of HDR Brachy Accidents.
- Gerbaulet, et al. GEC ESTRO Handbook.
- Kubo, et al. AAPM Report No. 59, HDR.
- Podgorsak. IAEA. Radiation Oncology Physics.
- IAEA-TECDOC-1274. Calibration of Brachy Sources.
- IAEA-QUATRO, Comprehensive Audits Tool.
- IAEA-Setting up a radiotherapy program: clinical, medical physics, radiation protection and safety.
- Venselaar, et al. ESTRO Booklet No. 8.
- IAEA-Safety Report Series No. 17 – lessons learned.
- EC-Guidelines on education and training in radiation protection for medical exposures.
- ASTRO-Safety is no Accident. …and others…

Radiation Protection in Brachytherapy

STAFF CONSIDERATIONS



LDR Staff Dose Potential

Manipulating

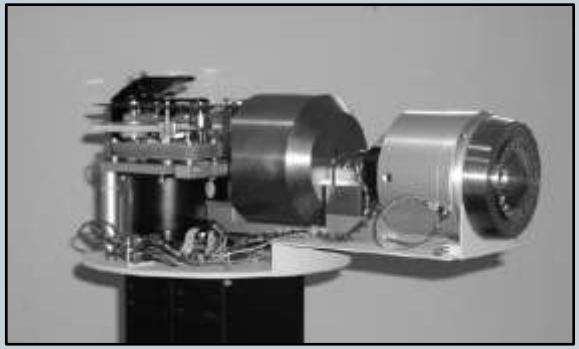
- Contamination from leaking or cut sources.
  - Wipe tests.
- Unshielded sources.
  - Shield, control, monitor.
- Lost sources.
  - Inventory cradle to grave.
- ALARA precautions not followed.

Seed / Spheres

- Prostate Implantation
  (Schwartz 2003)
  - Fluoro Time.
  - 100 µSv/case DDE.
  - 700 µSv/case SDE extrem.
- Spheres –
  - Fluoro Time.
  - Contamination.
  - Beta doses.

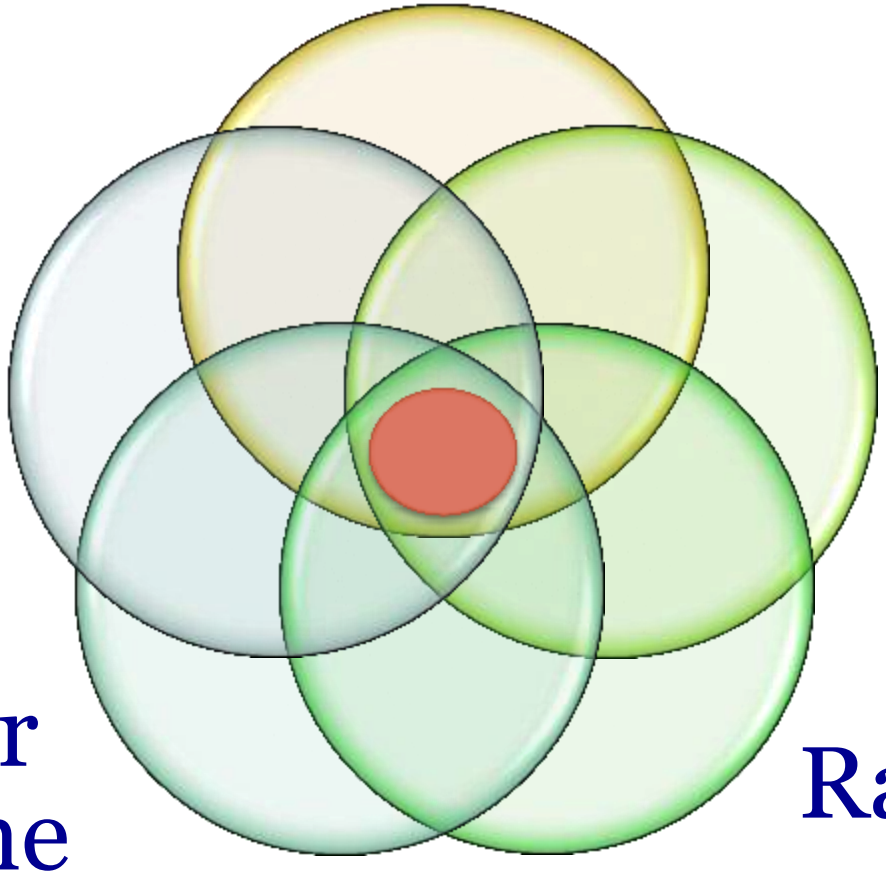
HDR Techniques Lower Staff Dose *IF*:

- Quality Management is implemented.
- Facility is carefully designed/shielded.
- Radiation monitoring is present.
- Equipment is tested and has preventive maintenance regularly.
- Packaged and shipped accordingly.
- Wipe tests for contamination.
- Labeled appropriately.
- Care when changing sources …



Blurring of Brachytherapy Boundaries

Radiation Oncology



Fluoro - Guided

Medical Physics

Nuclear Medicine

Radiology

Optimizing Radiation Protection

"Tried and True" Defined Rad Prot	"Newer and Developing" Need to define Rad Prot

• Time
• Distance
• Shielding
• Planning
• Training
• Quality Management
	• Conformal Balloons.
	• Intraoperative (again).
	  ○ Electronic Brachy.
	  ○ µSpheres.
	  ○ P-32 flexible plaque for dura of spine and brain.
	• Pre-operative
	  ○ Rad Seed localizations.

Radiation Protection in Brachytherapy

PUBLIC CONSIDERATIONS

Low Public Exposures

HDR ~ No dose.

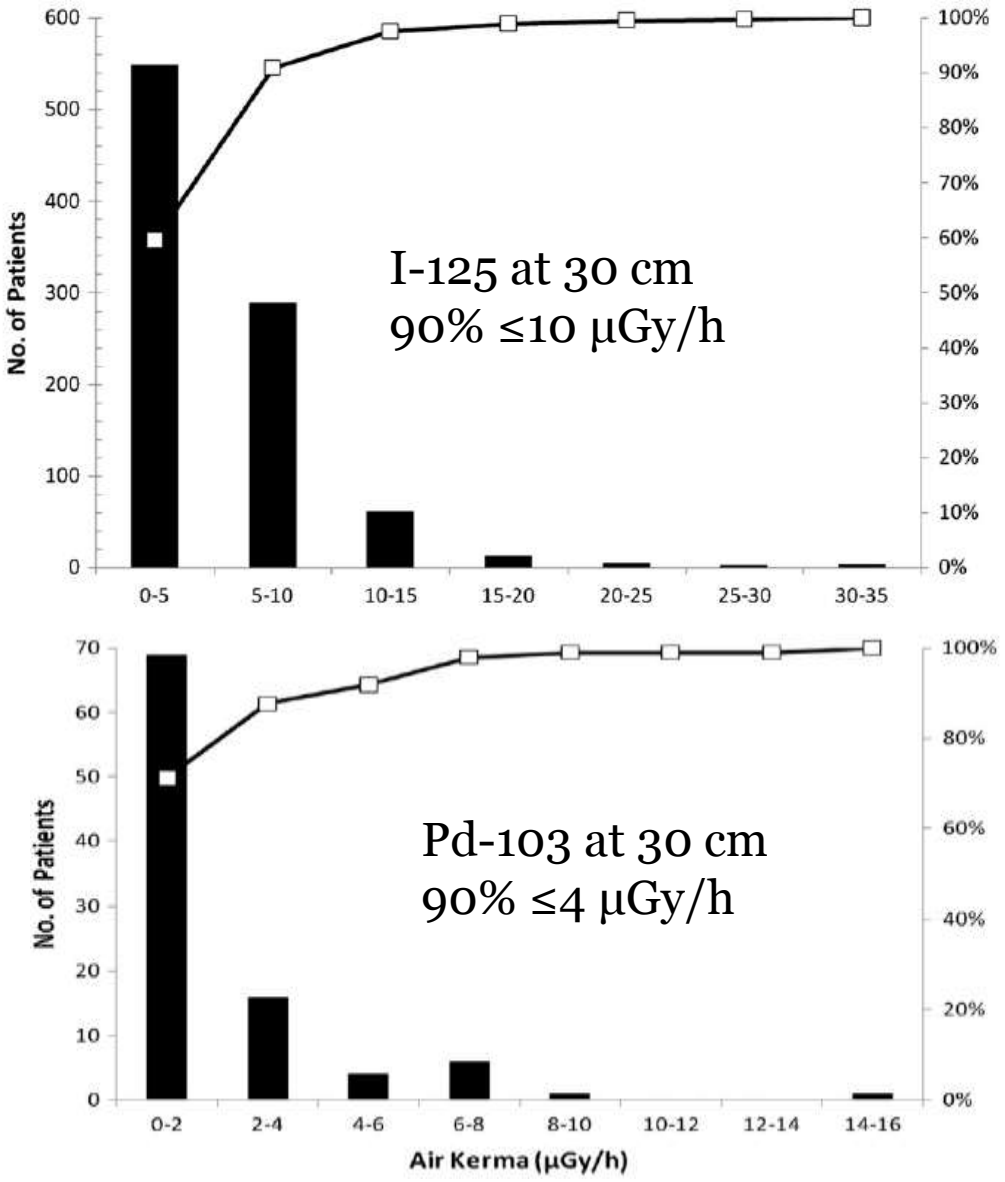
LDR ~

<u>Permanent</u>

Low energy photon or short-range beta results in low public exposure potential. Less restrictive instructions

<u>Temporary</u>

Time, Distance, Shielding and Planning lowers public exposure potential.



(Dauer, 2010)

ICRP-98 on Permanent Implants

- Use is increasing.
- No adverse effects to medical staff and/or patient's family reported.
- Annual dose from patients to family or household members remains << 1 mSv.
- Expulsion of sources is rare.

Radiation safety aspects of brachytherapy for prostate cancer using permanently implanted sources

ICRP Publication 98

- Cremation can be allowed if 12 months have elapsed or special measures may be needed.
- Patient needs specific recommendations.

  -see Dauer et al 2010 for followup.

Security and Safeguards

Several thousand facilities worldwide.

10,000+ Source Shipments/y.

Need for more equipment and sources in next decade must consider safeguards.

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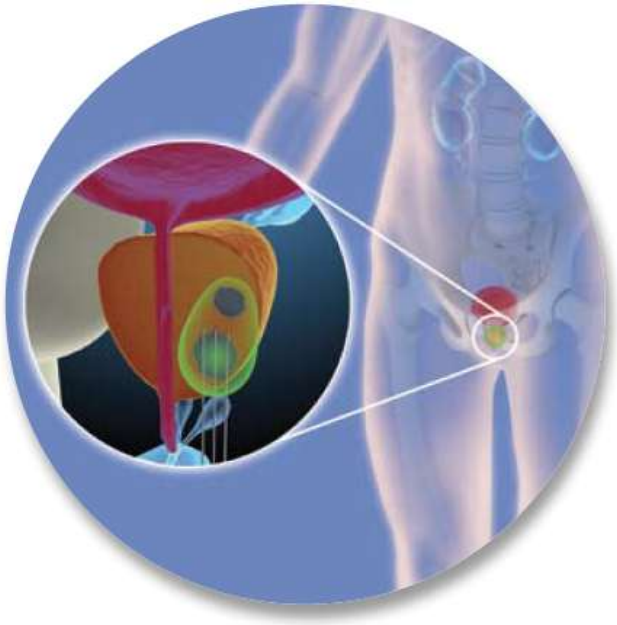
CONCLUSIONS



Conclusions

- Brachytherapy:
  - Continues be an important radiotherapeutic option.
  - Should increase in next decade - recognized as ‘high value’.
- Emphasis on basic radiation safety principles needed as current methods mature and newer techniques are developed.
- Significant opportunities for improvement exist in *implementing* Quality Management.
- Infrastructure is lacking:
  - Equipment resources and availability.
  - Human resources and training.
  - Safeguards for sources.

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