



International Conference on Modern Radiotherapy

Advances and Challenges in Radiation Protection of Patients

2 - 4 December 2009 - Versailles, France

www.conference-radiotherapy-asn.com

Paradigms of external radiotherapy and brachytherapy.

New techniques, new benefits and new risks

“Advances in Brachytherapy”

Pr Didier Peiffert

Dpt of Radiation Oncology

Centre Alexis Vautrin

Vandoeuvre les Nancy - FRANCE

Brachytherapy (or *Curiethérapie*)
is a technique of treatment by irradiation
using radioactive elements placed
close or inside the tissues.

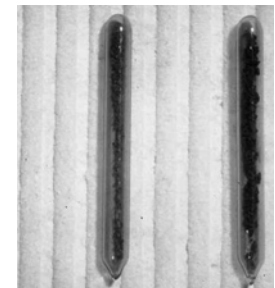
First applications at the Institut du Radium



Pavillon Pasteur



**Dr Claudius Regaud
In 1912**



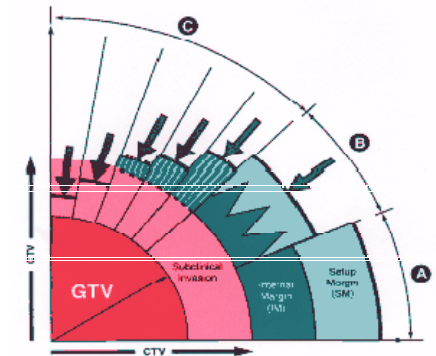
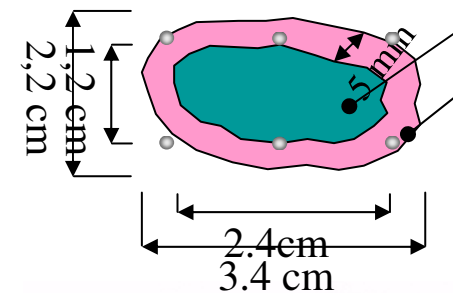
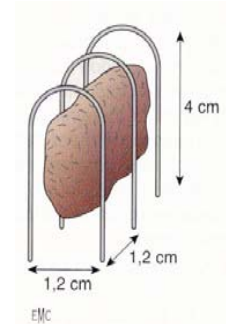
Patterns of care for Brachytherapy (PCB) 2002

- **1064** European radiotherapy centres
- 42% (450) provide brachytherapy.
- **41,130** patients were treated with brachytherapy

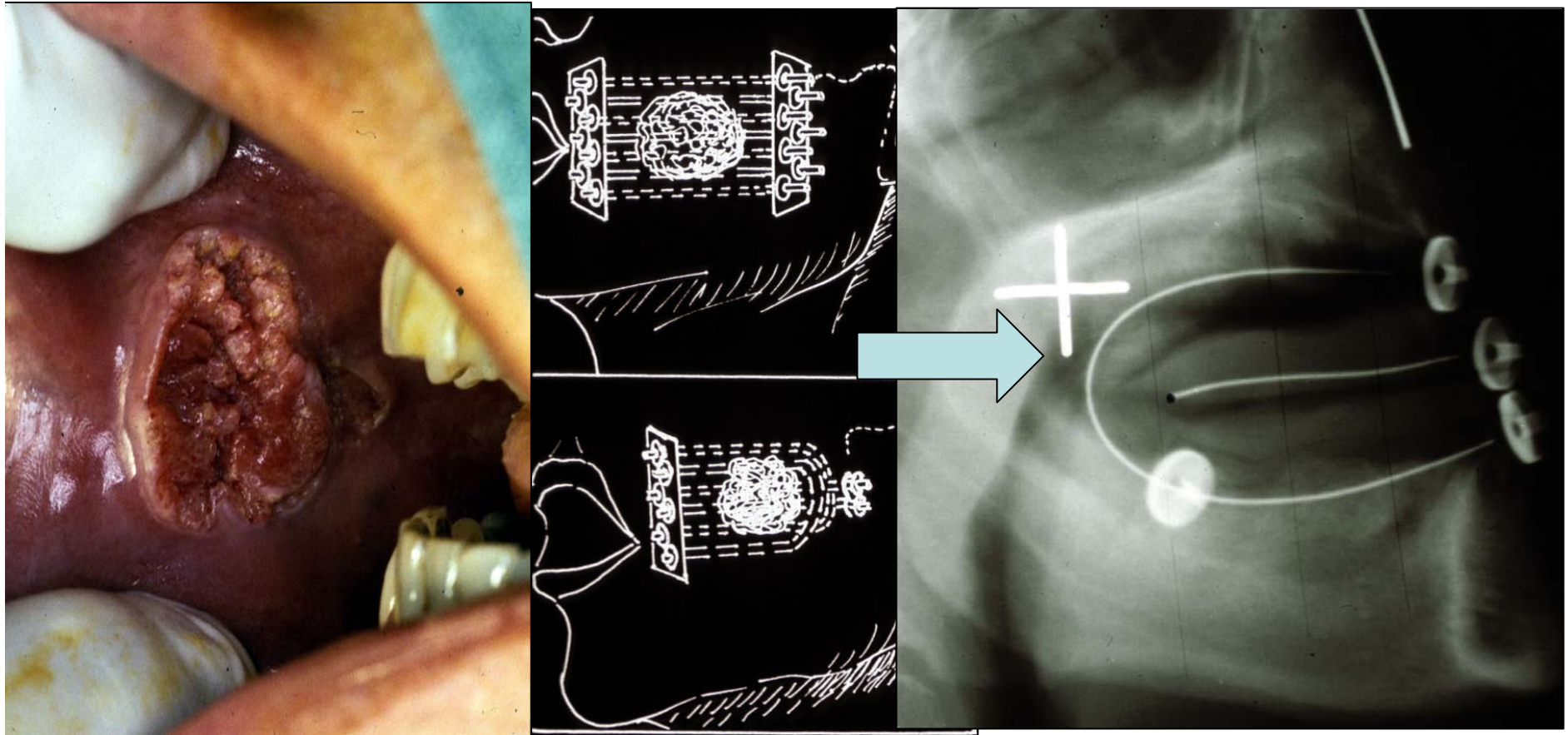
Advantages of brachytherapy

To deliver a high dose to the primary

- Rapid fall-off at periphery
 - To spare the critical normal tissues
- On a small volume
 - movements of the patients and of the organs
- Continuous low dose rate
 - To improve the therapeutic index
- Short overall treatment duration
 - To avoid repopulation



Conformal BT



Main Brachytherapy indications

Head and neck

Prostate

- Skin
- lung

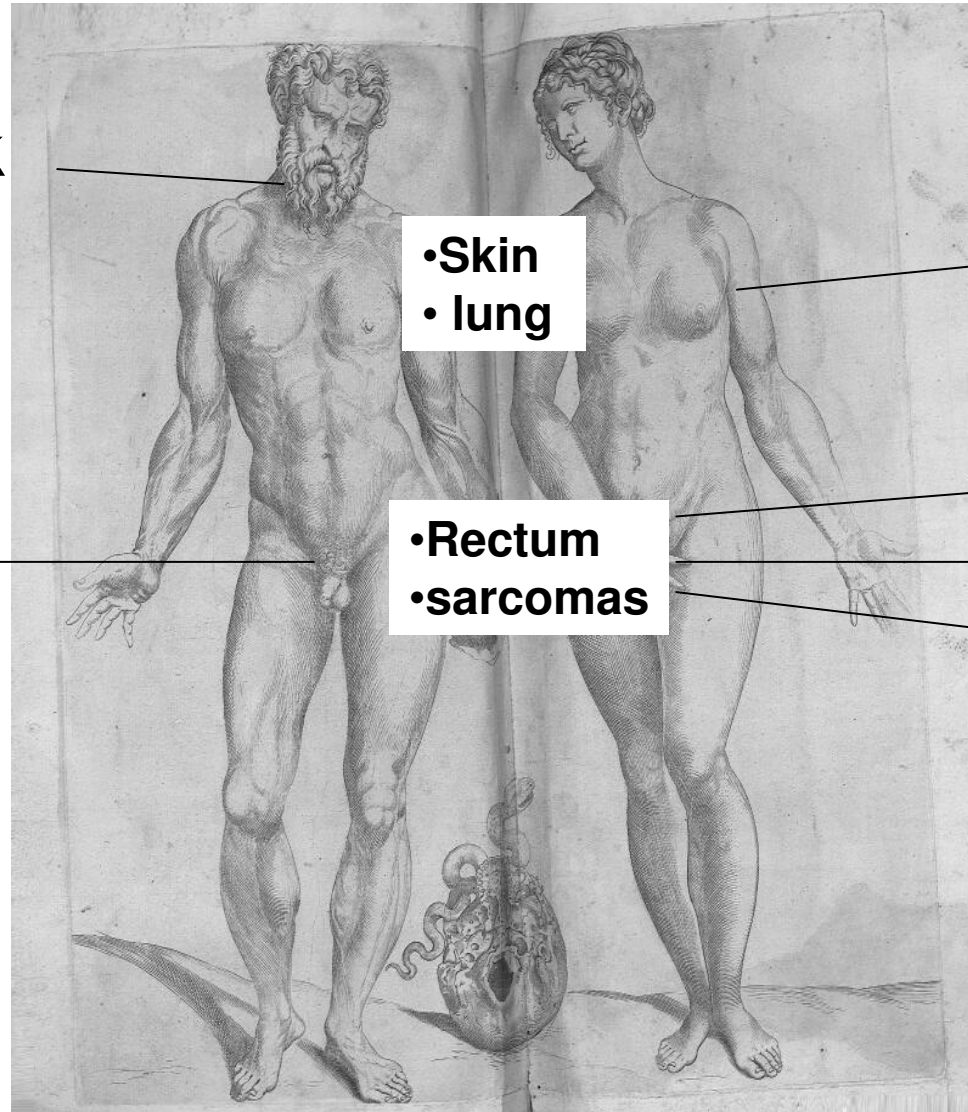
Breast

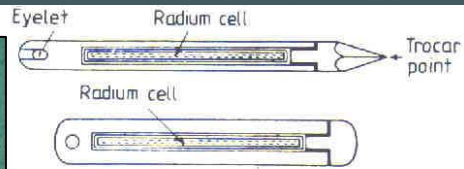
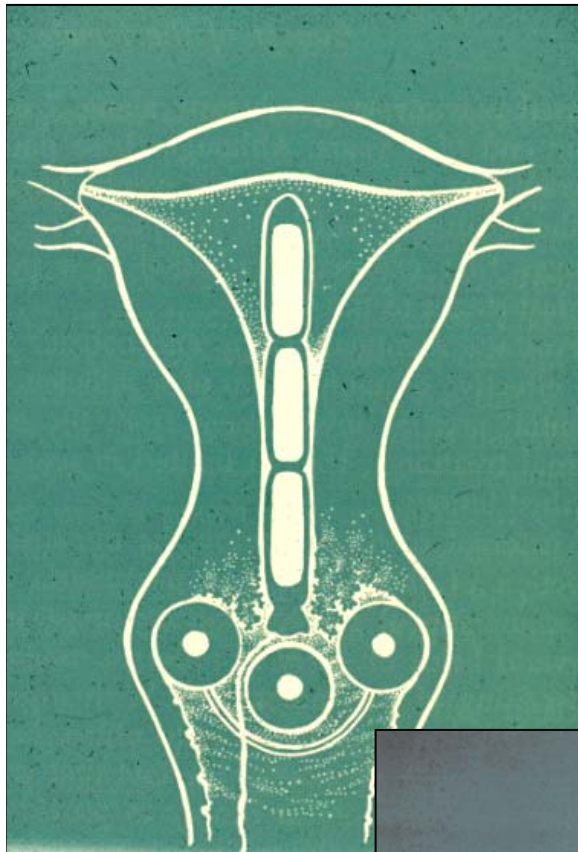
Uterus

Cervix

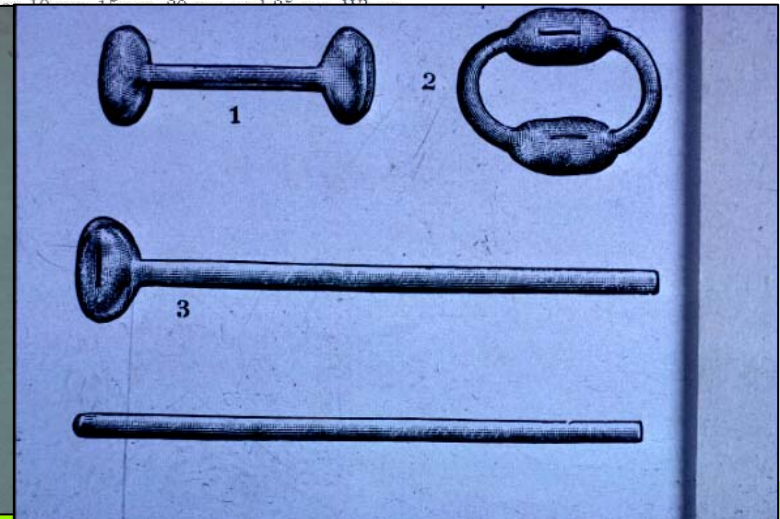
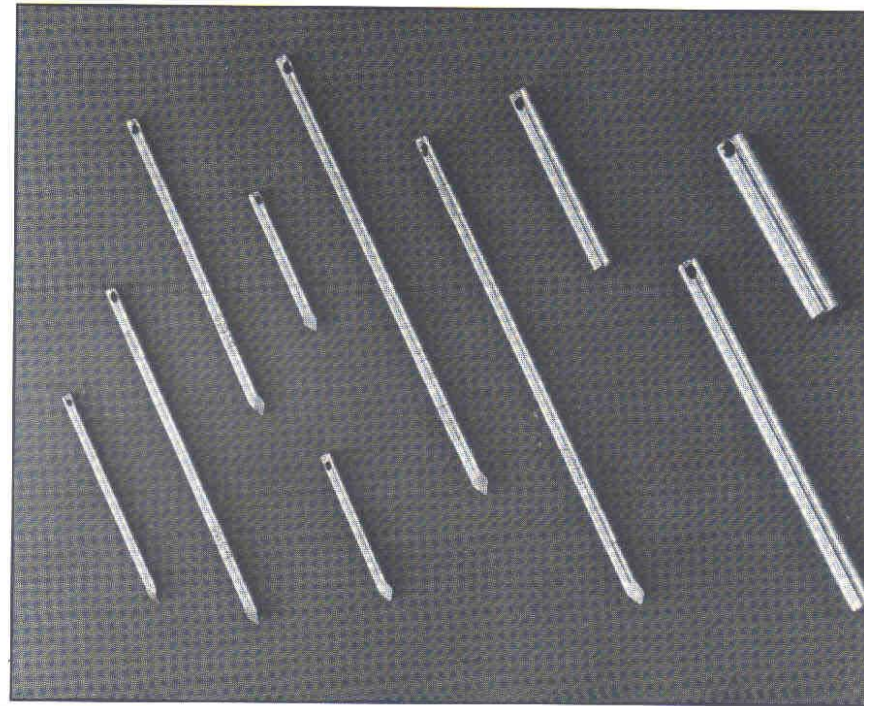
Anus

- Rectum
- sarcomas

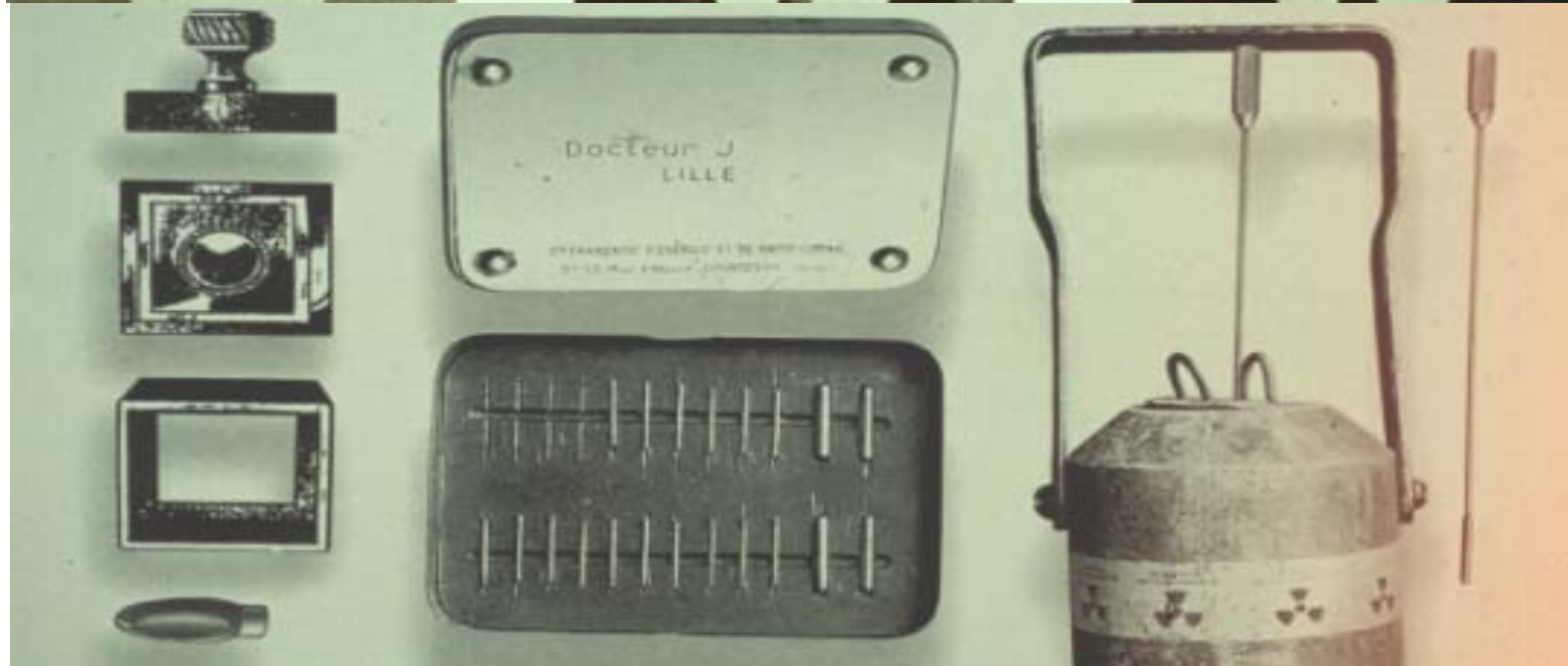




[3.17] Although there was a large range of linear radium sources, tubes and needles, in terms of geometrical and active length and linear activity (milligram radium/cm), the basic design from the early 1920s was essentially that shown in the schematic diagram. Eyelets were used to suture a needle to the patient's tissue to prevent the possibility of its involuntary removal before the end of treatment, or to attach string threads to a tube to enable removal, such as from the uterus or vagina after gynaecological brachytherapy had been completed. Some designs had removeable screw-on ends so that different radium cells could be placed in the outer container, depending on the required treatment. Union Minière du Haut Katanga, the Belgian company, supplied such sources in the 1920s, but by the 1950s the Radiochemical Centre, Amersham (later Amersham International), who were then the major supplier of radium sources, had no screw-on end designs and certainly did not supply any radium cells which, because of their very thin walls, were of a much



radium needles and tubes



“ Hot Holding” of radium needles and tubes

Radium 226 abandoned

1/2 life 1600 years

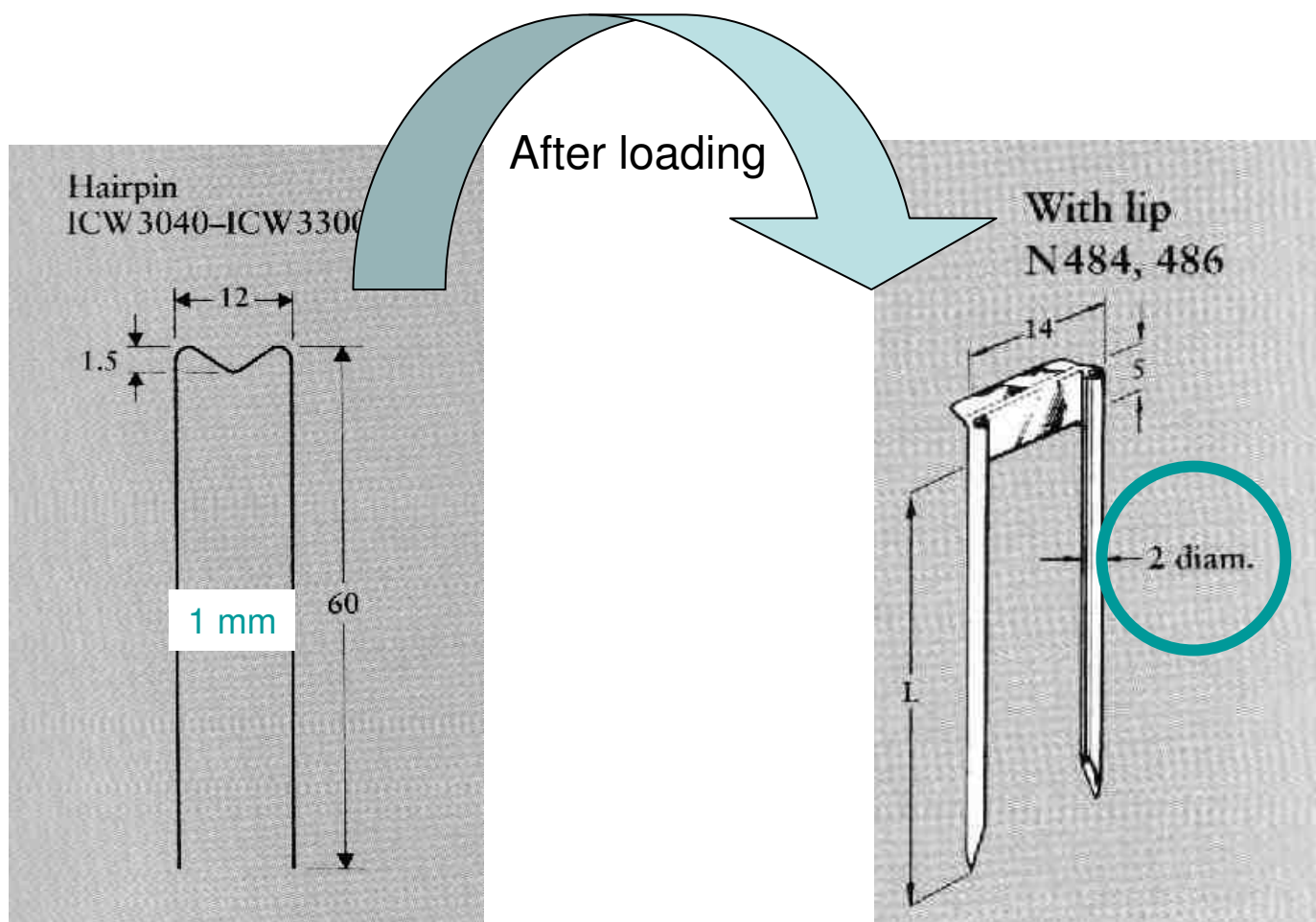
Man-made new isotopes in wires and/or discrete encapsulated sources:

- Short 1/2 life
- Miniaturised
- Afterloading techniques



Radio Nuclide	Half Life $T_{1/2}$	λ (s^{-1})	Mass for 100 MBq (μg)	Average Photon Energy (keV)	Half Value Layer lead * (mm)	Tenth Value Layer lead ** (mm)
^{137}Cs	30.2 y	$7.27 \cdot 10^{-10}$	31	662	6.5	22
^{192}Ir	74.1 d	$1.08 \cdot 10^{-7}$	0.29	380	6.0	16
^{125}I	60.2 d	$1.34 \cdot 10^{-7}$	0.16	28	0.03	0.1
^{103}Pd	17 d	$4.72 \cdot 10^{-7}$	0.04	21	0.02	0.1
^{226}Ra	1600 y	$1.37 \cdot 10^{-11}$	2735	830	16	45

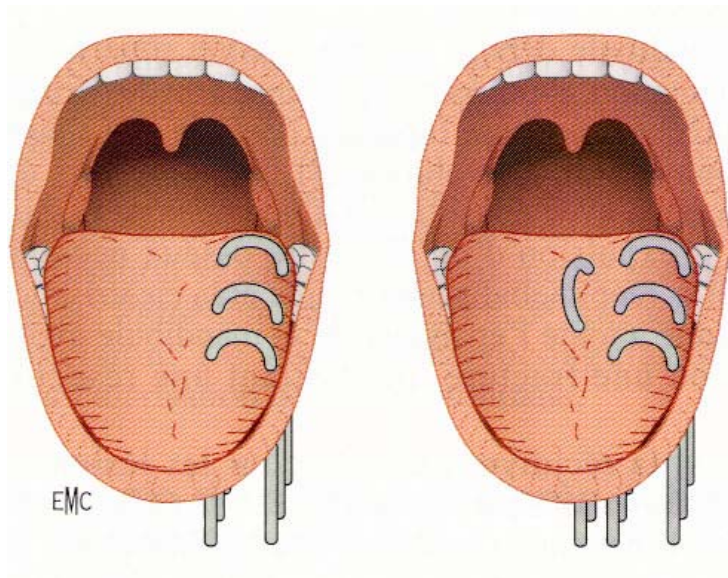
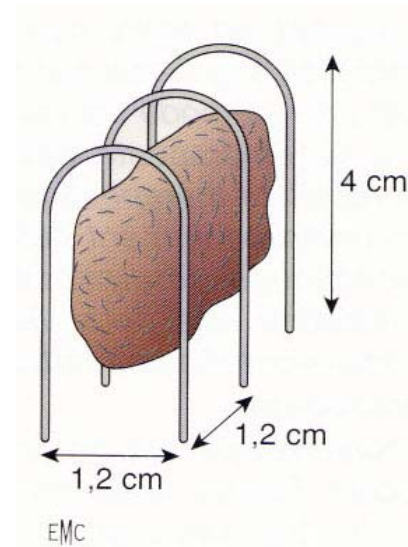
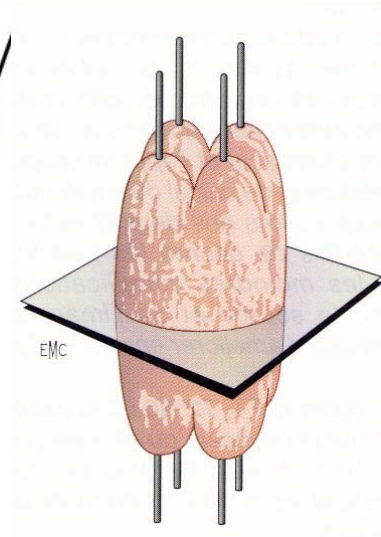
Iridium 192



wire-type source

guiding needles

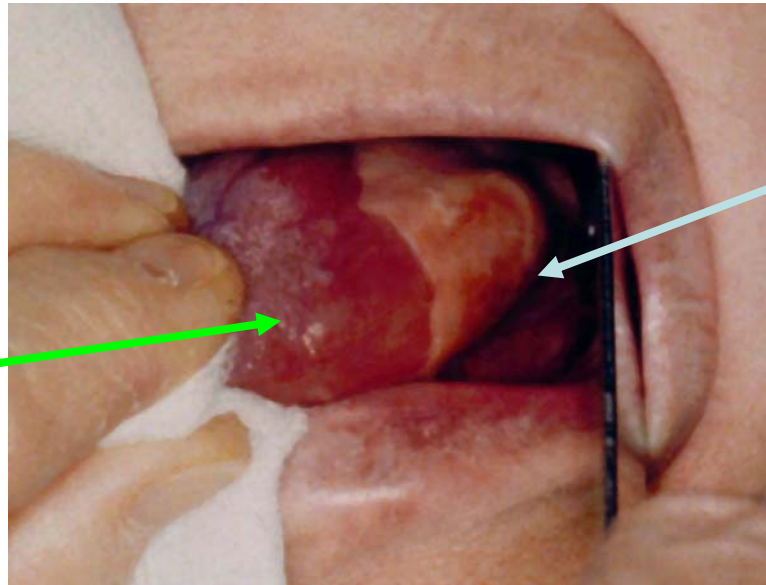
Rules for implantation (Paris System)





Low dose
Sparing NT

Acute Mucositis



High curative dose
➤ 65 Gy

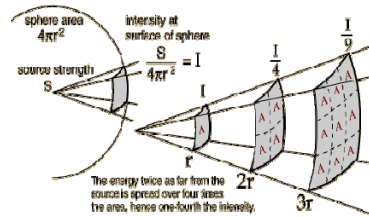
Healing at 2 Months



Preparation of Ir192 sources and manual afterloading

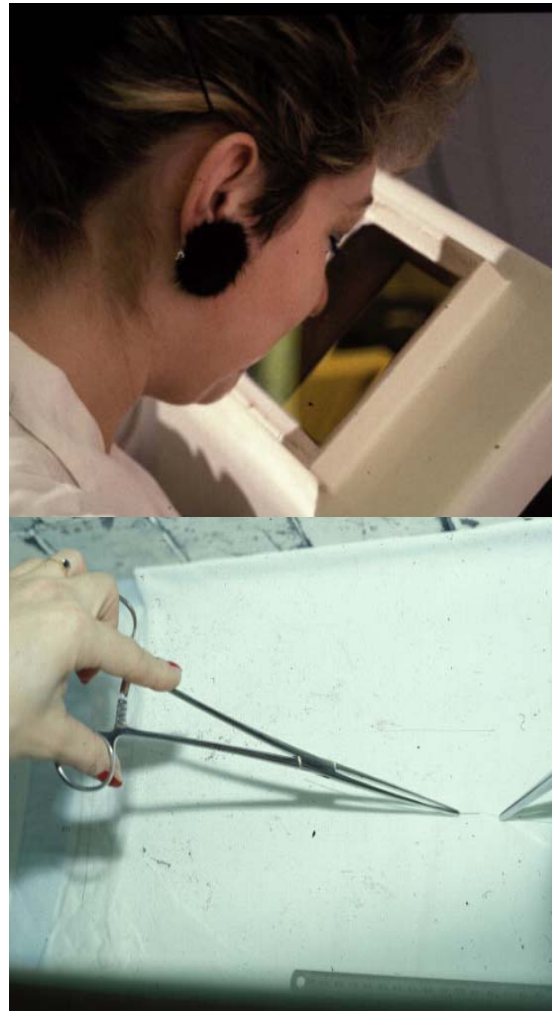
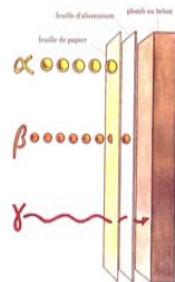


distance



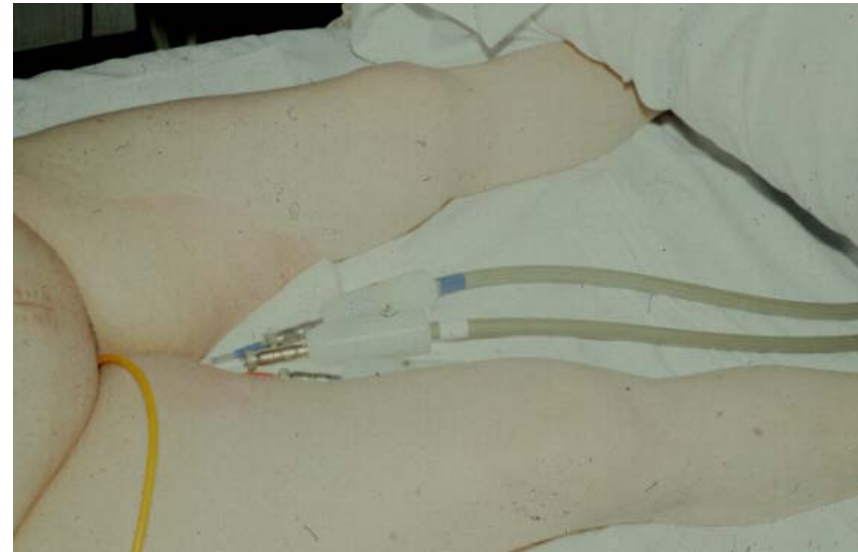
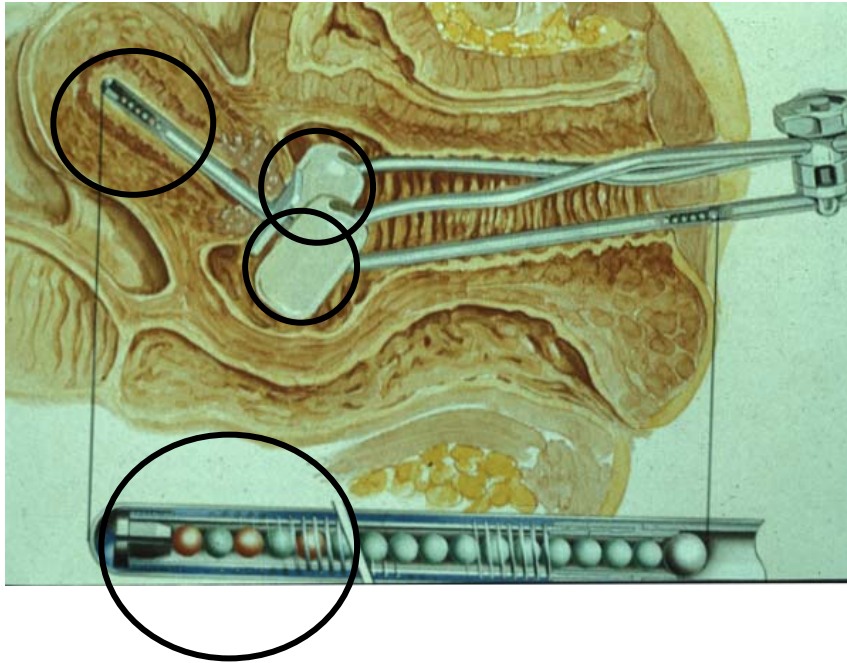
time

shielding



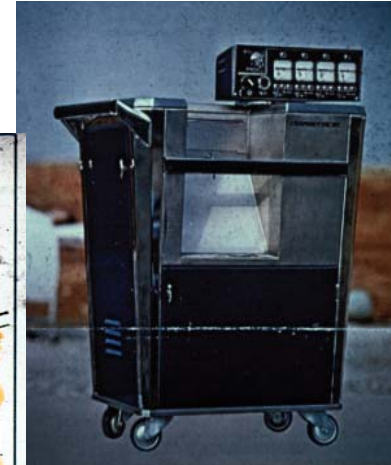
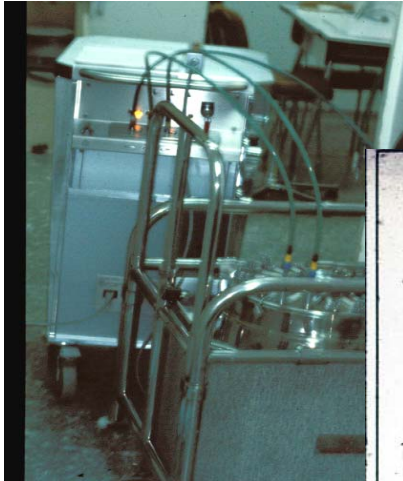
Reduce the exposure as much as possible

Cesium 137 sources , tandems , and afterloaders



Reduce the exposure as much as possible

Afterloaders



Reduce the exposure as much as possible

Low dose-rate $< 2 \text{ Gy / h}$

— LDR

0

12 h

24 h



Tumour control

Role of interstitial brachytherapy in oral and oropharyngeal carcinoma: Reflection of a series of 1344 patients treated at the time of initial presentation

MONIQUE PERNOT, MD, SYLVETTE HOFFSTETTER, MD, DENIS PEIFFERT, MD,
MICHEL LAPEYRE, MD, CHRISTIAN MARCHAL, MD, ELISABETH LUPORSI, M
Vandœuvre Les Nancy, France

(Otolaryngol Head Neck Surg 1996;115:519-26.)

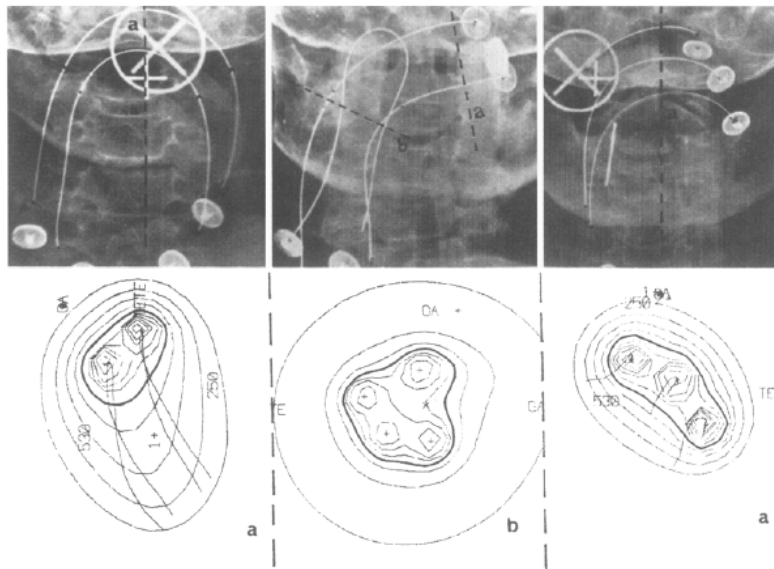


Fig. 5. **a**, Brachytherapy of palatotonsillar region. with bilateral loops passing inside the pillars and the soft palate. **b**, Unilateral loops cover the pharyngoglossal sulcus because of an additional loop in the tongue. **c**, A third wire covers the junction of the soft palate with the hard

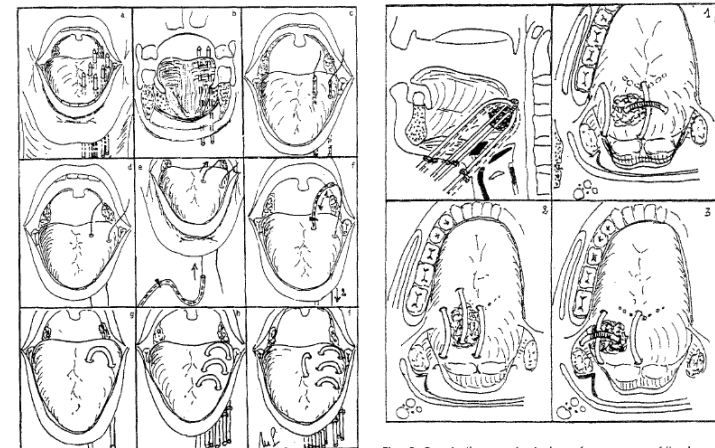


Fig. 2. Brachytherapy technique for cancers of the base of the tongue.

Otolaryngology -
Head and Neck Surgery
Volume 115 Number 6

PERNOT et al. 523

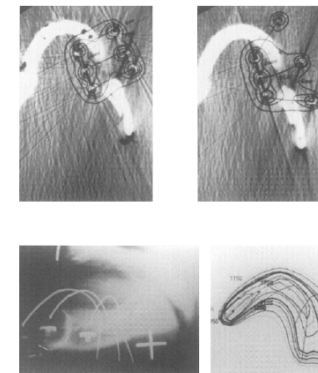


Fig. 4. Technique of loop brachytherapy for cancers of the buccal mucosa. Posterior part of loop is used to pre-

5-10 years Late effects



Int. J. Radiation Oncology Biol. Phys., Vol. 37, No. 3, pp. 577-585, 1997
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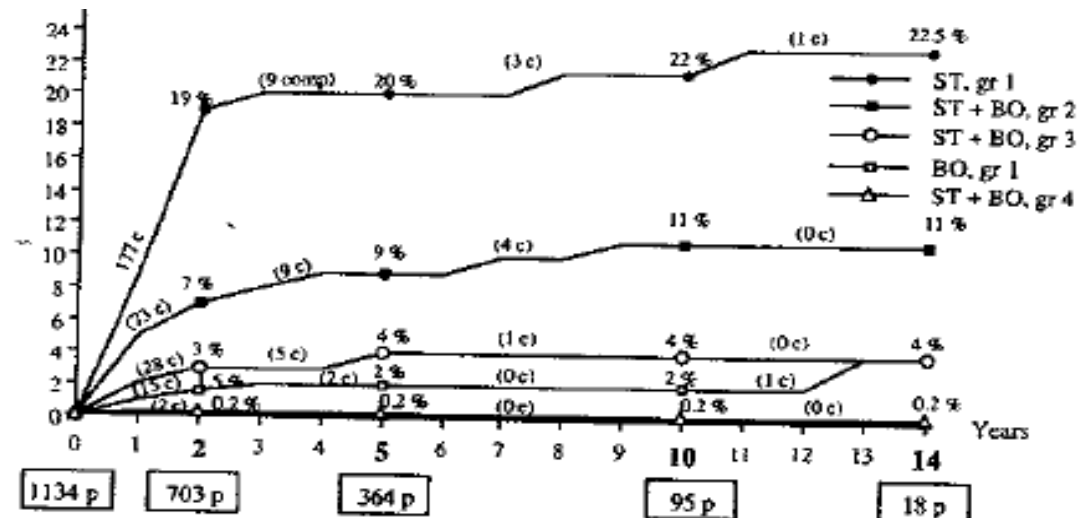
PII S0360-3016(96)00612-8

● Clinical Investigation

COMPLICATIONS FOLLOWING DEFINITIVE IRRADIATION FOR CANCERS OF THE ORAL CAVITY AND THE OROPHARYNX (IN A SERIES OF 1134 PATIENTS)

MONIQUE PERNOT, M.D.,* ELISABETH LUPORSI, M.D.,[‡] SYLVETTE HOFFSTETTER, M.D.,*
DIDIER PEIFFERT, M.D.,* PIERRE ALETTI, Ph.D.,^{||} CHRISTIAN MARCHAL, M.D.,[†]

Total Dose
Dose rate



LDR became a standard

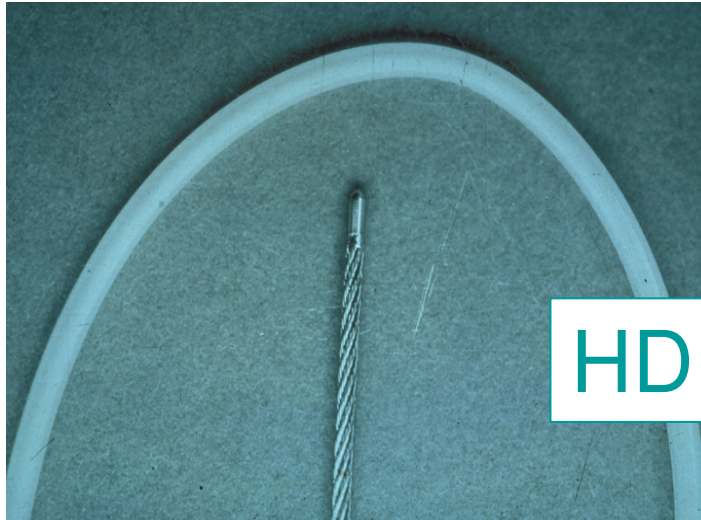


LDR improved but ...
no real innovations

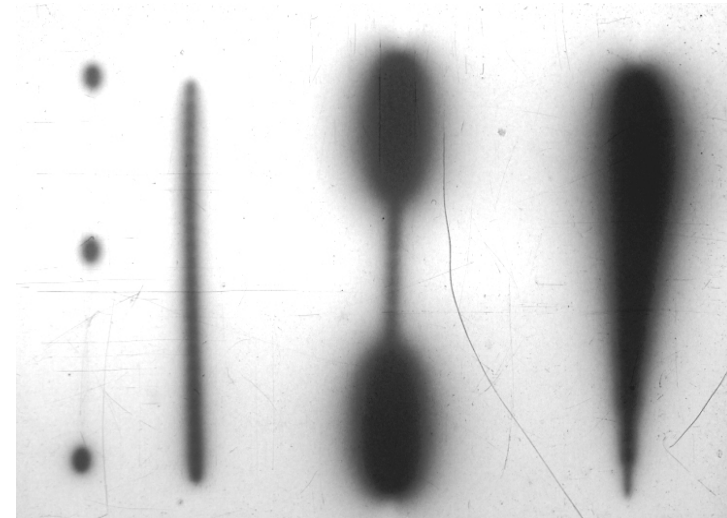


New Techniques

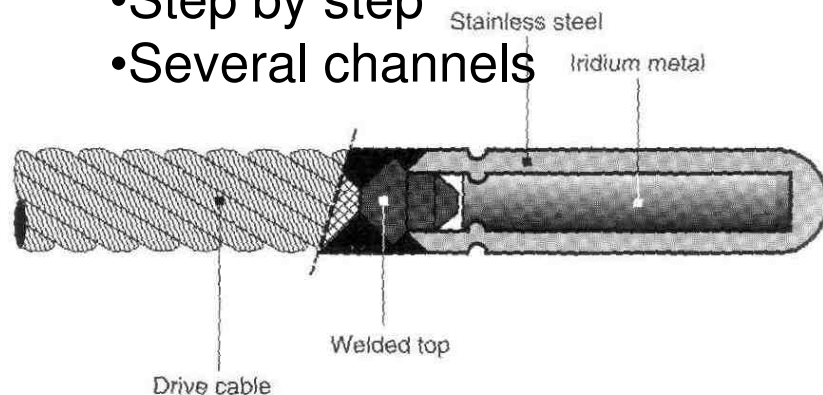
Stepping source technology



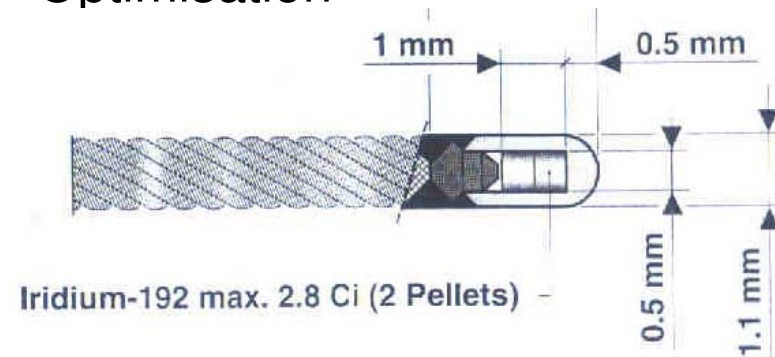
HDR



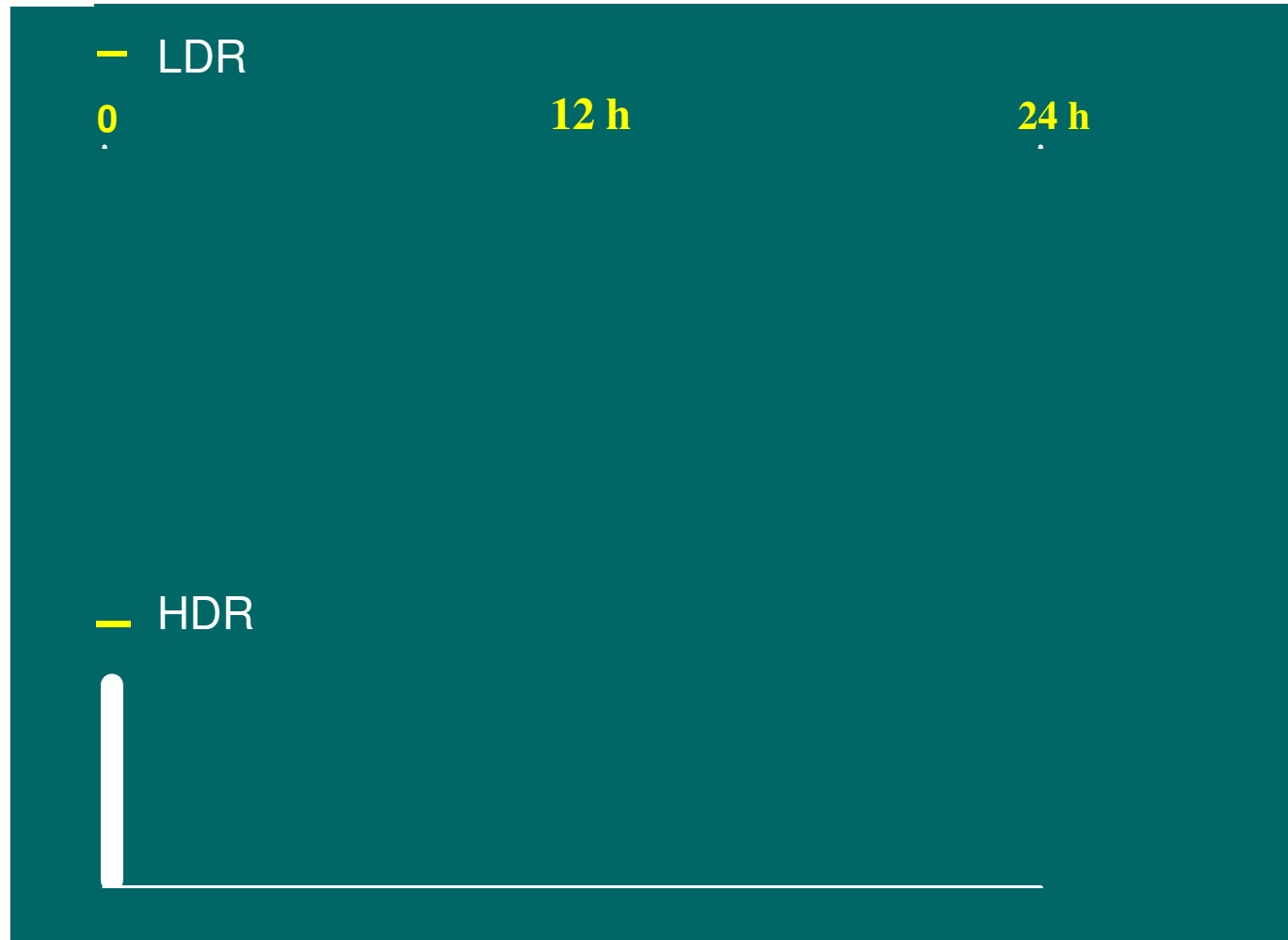
- Ponctual source of Ir192
- High activity 370 GBq (10 Ci)
- Drive cable
- Step by step
- Several channels



- Dwell positions / Dwell times
- Piloted by a computer
- Mimiking trains of sources or wires
- Optimisation



High dose Rate HDR > 12 Gy/ h



HDR was innovative



But potentially dangerous , due to the biological effects on normal tissues

New Techniques

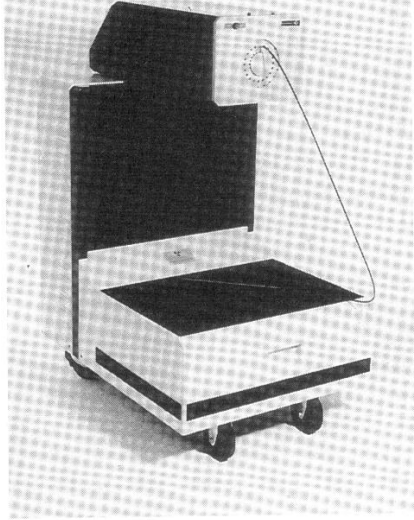


Fig. 1. Curiatron 192 HDR Unit. (Courtesy of Christian Sumeghy, CIS Bio International, Cedex France)



Fig. 2. microSelectron HDR Unit. (Courtesy of Miles Mount, Nucletron Corporation, Columbia, Maryland)



Fig. 3. GammaMed 12i HDR Unit. (Courtesy of Steve Woodruff, Frank Baker Associates, Pequannock, New Jersey)

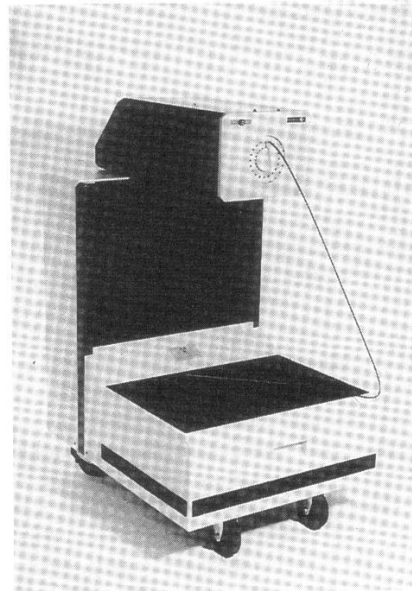


Fig. 4. Omnitron 2000 HDR Unit. (Courtesy of Tony Bradshaw, Omnitron International, Inc., Houston, Texas)

New technology
High Number of patients
Out patient treatment

> 1 500 afterloaders in the World
10 000 sources per year
> 500 000 procedures per year

New Techniques

Radium



Iridium



Afterloading

Dosimetry
Predictive rules
Clinical knowledge



LDR

Stepping sources



HDR

Biological effect



Technology
3D imaging
Optimisation

Pulsed dose Rate

— LDR



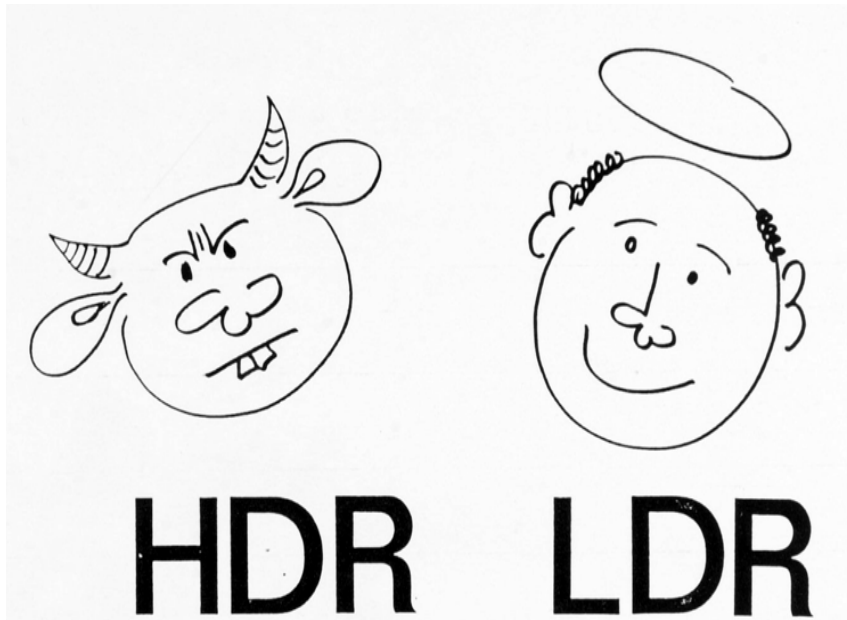
— Pulsed dose Rate PDR



— HDR

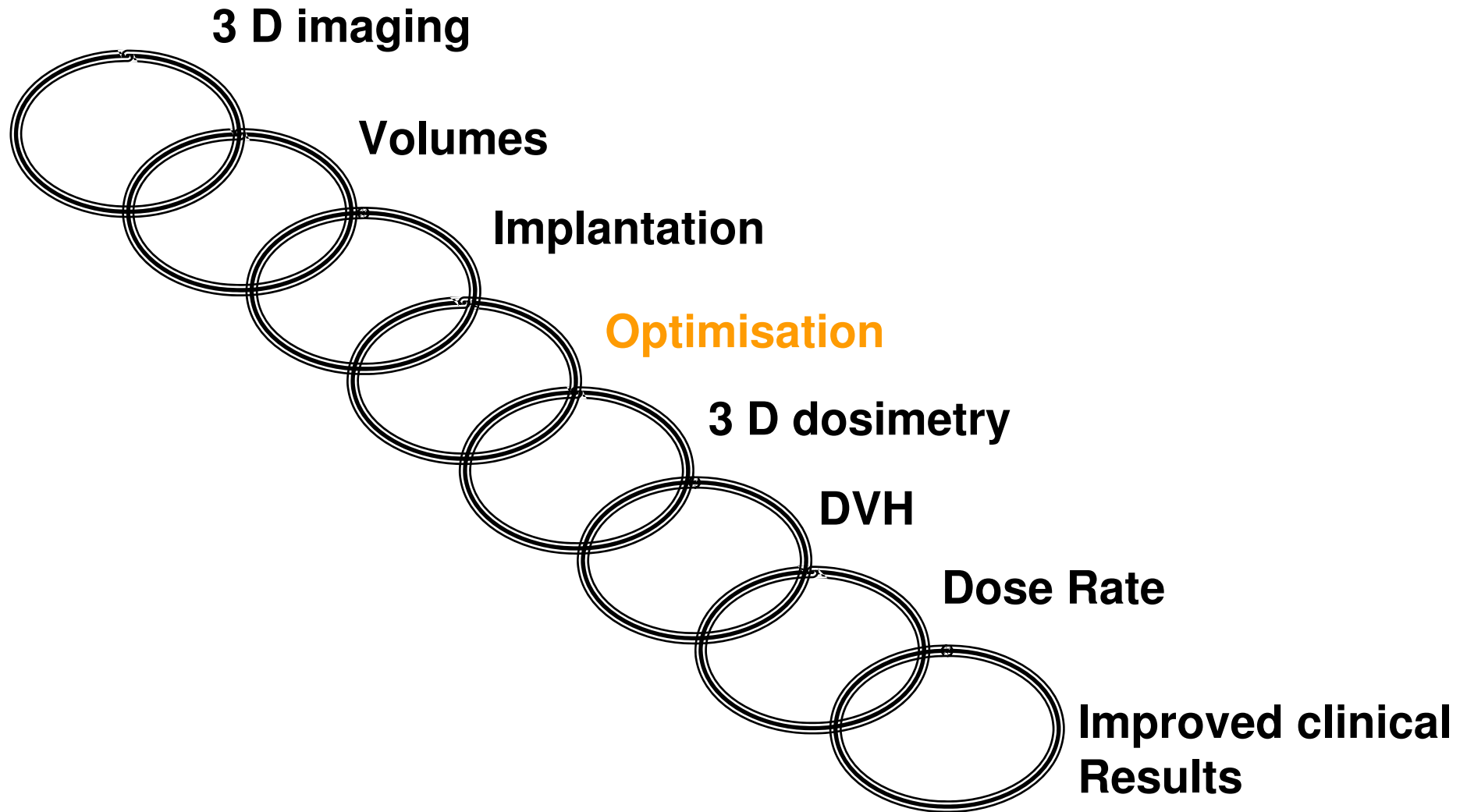


PULSED (LOW) DOSE RATE



THE BEST OF BOTH WORLDS !

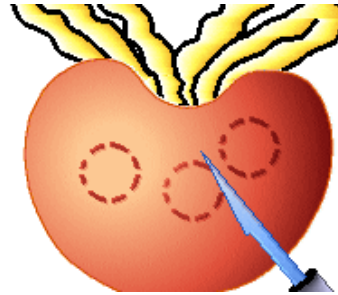
Conformal pulsed (low) dose rate



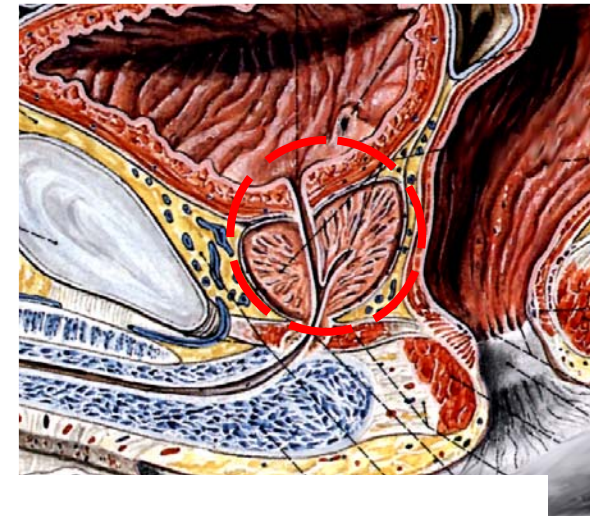
Permanent implants

combined

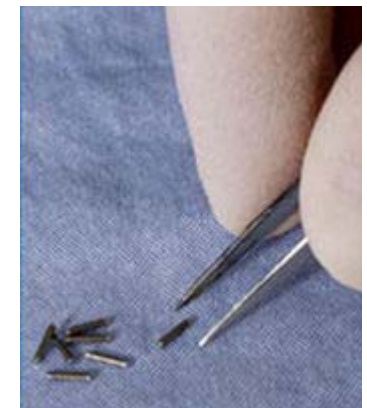
- a short half life
- with low energy



Prostate



Radio Nuclide	Half Life $T_{1/2}$	λ (s^{-1})	Mass for 100 MBq (μg)	Average Photon Energy (keV)	Half Value Layer lead * (mm)	Tenth Value Layer lead ** (mm)
^{137}Cs	30.2 y	$7.27 \cdot 10^{-10}$	31	662	6.5	22
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^{226}Ra	1600 y	$1.37 \cdot 10^{-11}$	2735	830	16	45

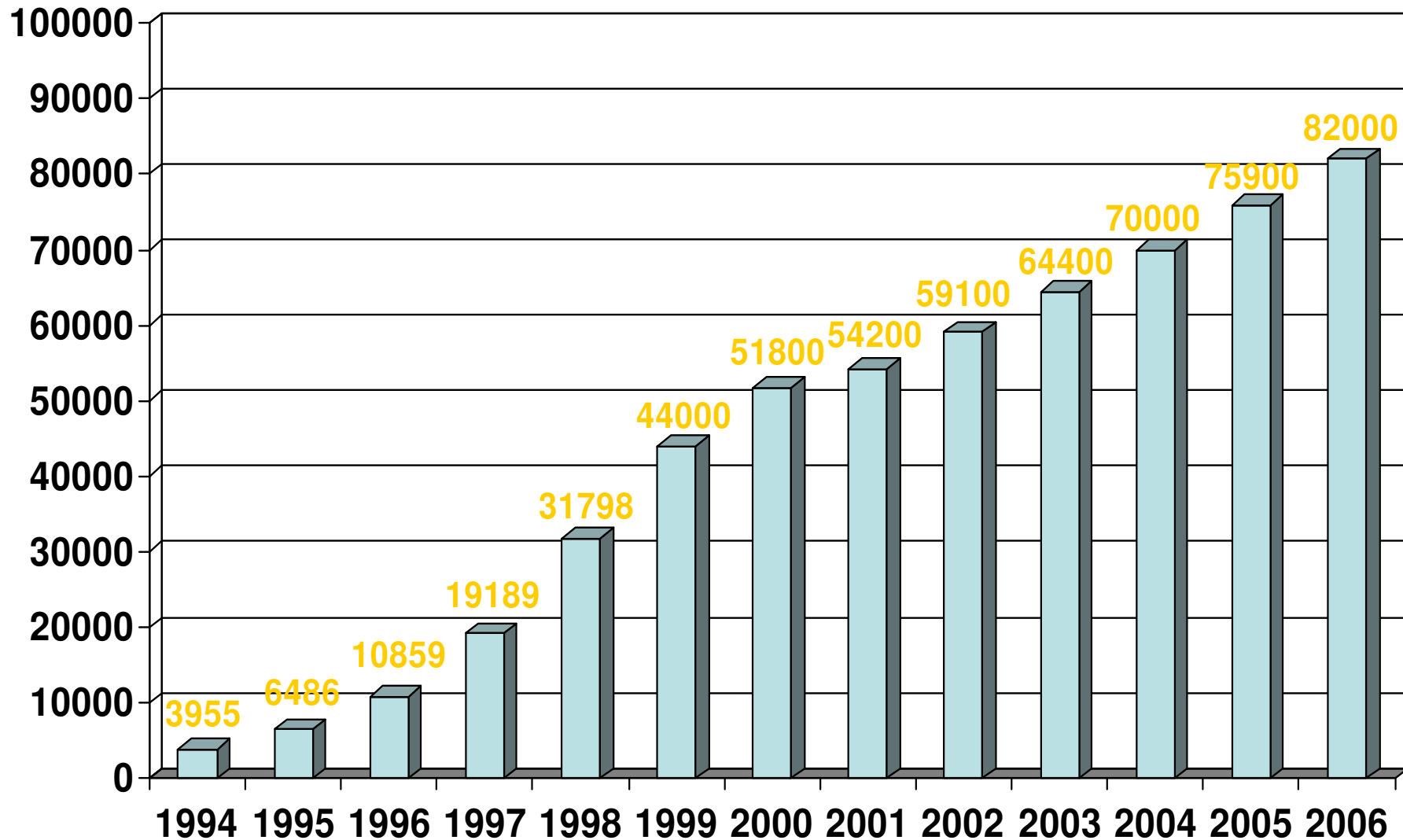


Iode 125 seeds



- Activity = 0,5 mCi
- $1/2$ life = 60 days
- Energy = 27-35 KeV
- $1/2$ layer lead: 0.03 mm

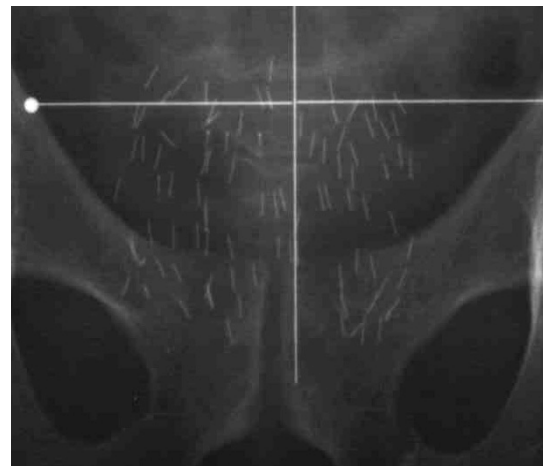
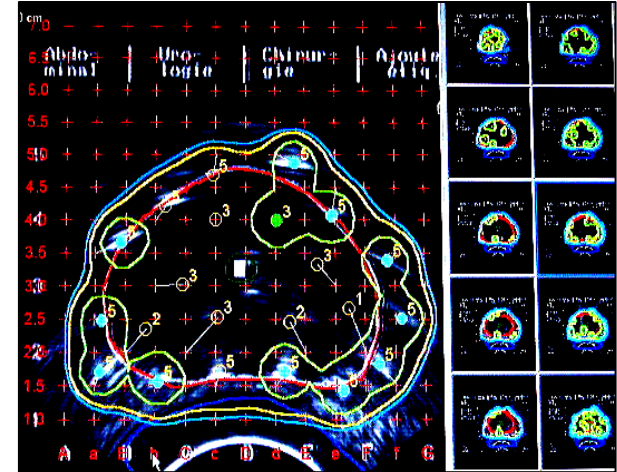
US Market Prostate Brachytherapy Cases



Numbers provided by industry

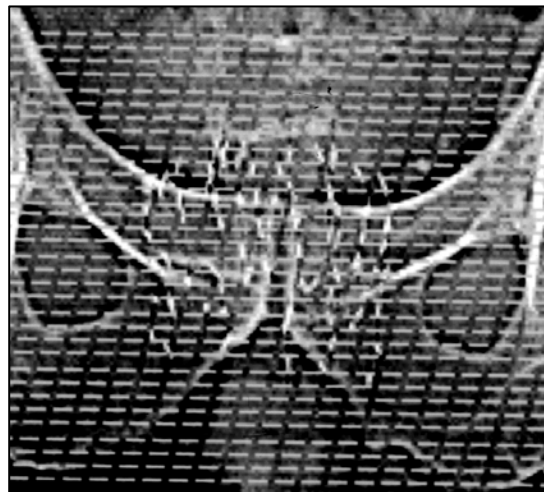
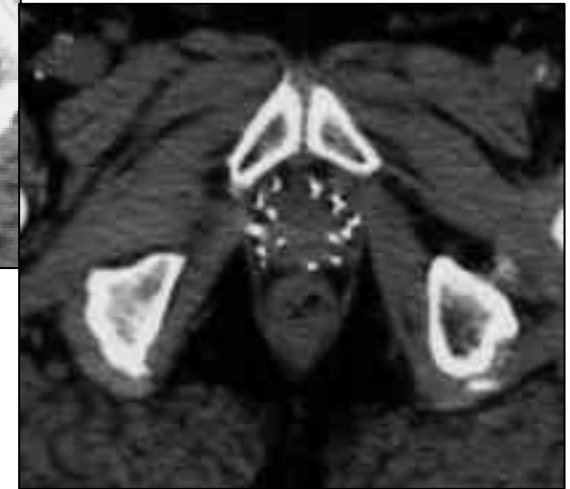
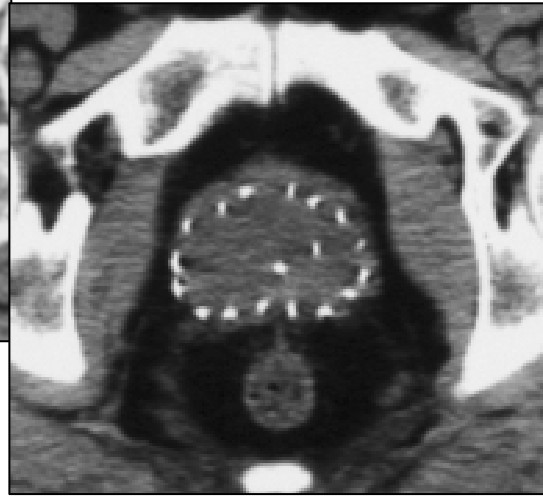
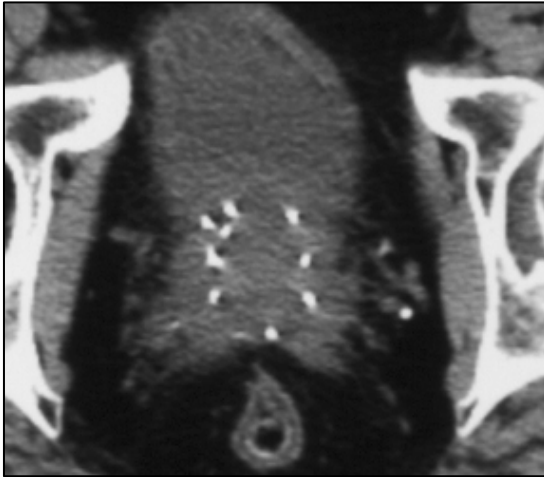
Millennium Research Group Predicted

Direct insertion under Ultrasonography



Post implant CT-Scan

Base



Apex

New benefits

To avoid sources to be lost



Even sources lost in the patient

To prescribe the dose-rate



- Exclusive Brachytherapy
- Dose effect: Brachytherapy D. > 62.5 Gy

- **Dose rate 0.3-0.5 Gy/h**

Mazeron et al : Radioth Oncol 1991;21;39–47

Coche-Dequeant et al : Bull Cancer / Radiother 1995;82:203

Pernot et al : IJROBP 1994;29:673–679

- (Pre-) Concept of quality index:

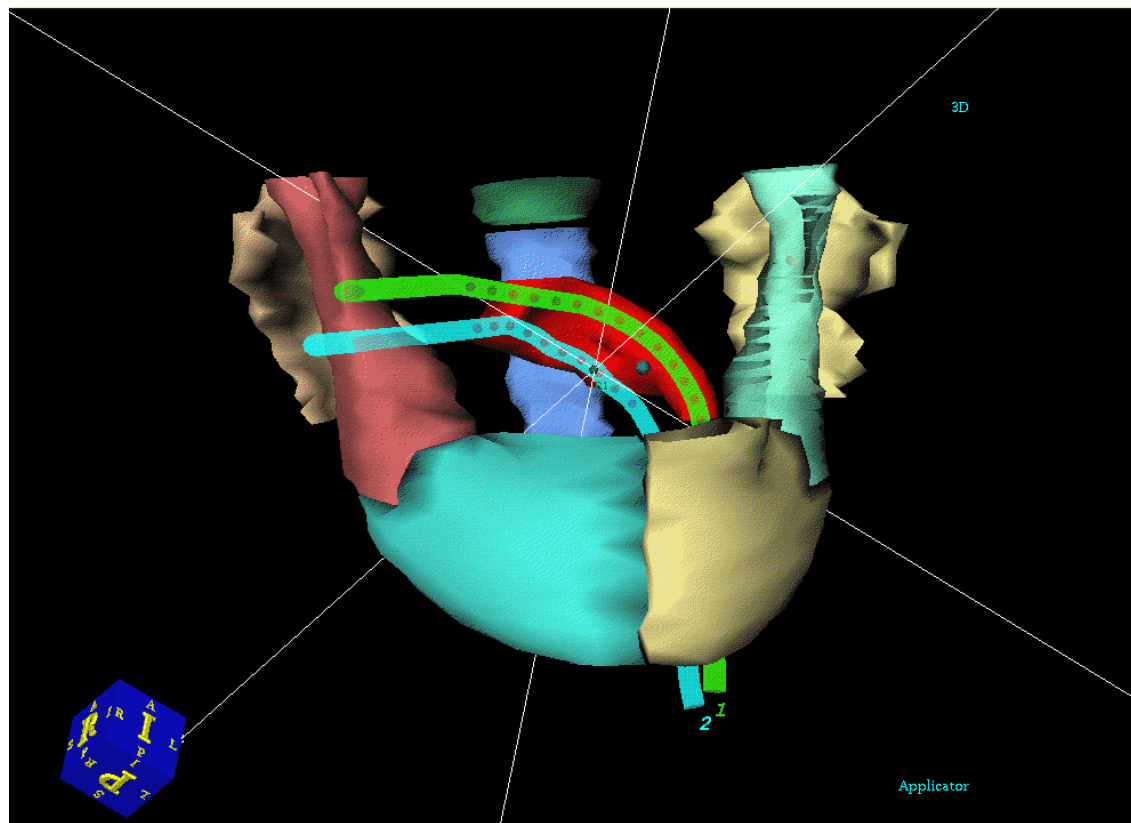
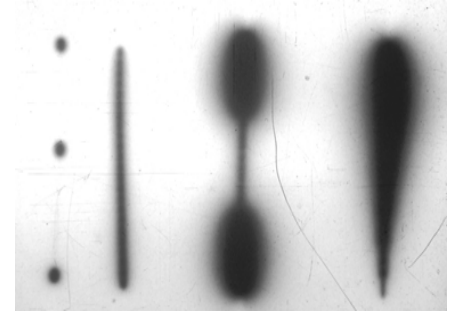
Treated V. > 120 % of GTV (2D concept)

5 y - local control: 75 % vs 52 %

Pernot et al : IJROBP 1994;29:673–679

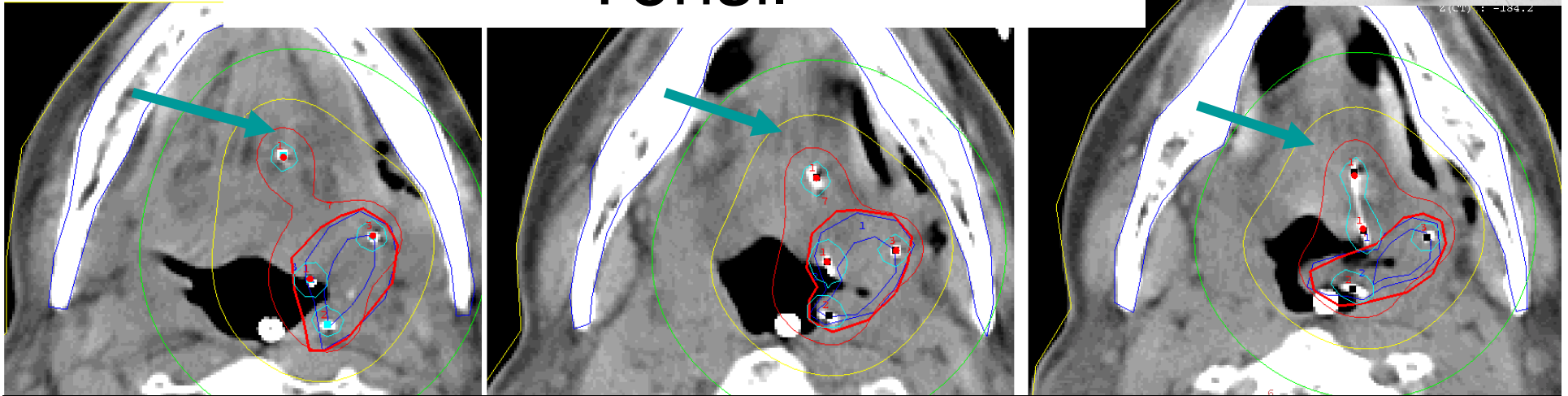
M.Tongue: Prognostic factors for local control

To Optimise the treated volume

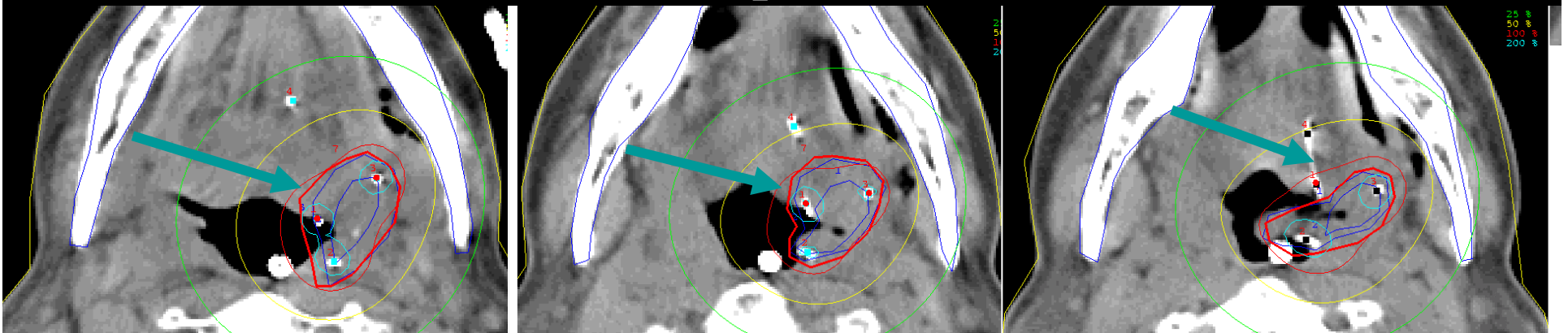


Ref: F. Ahmad, Radiother Oncol 2004

To Optimise the treated volume Tonsil

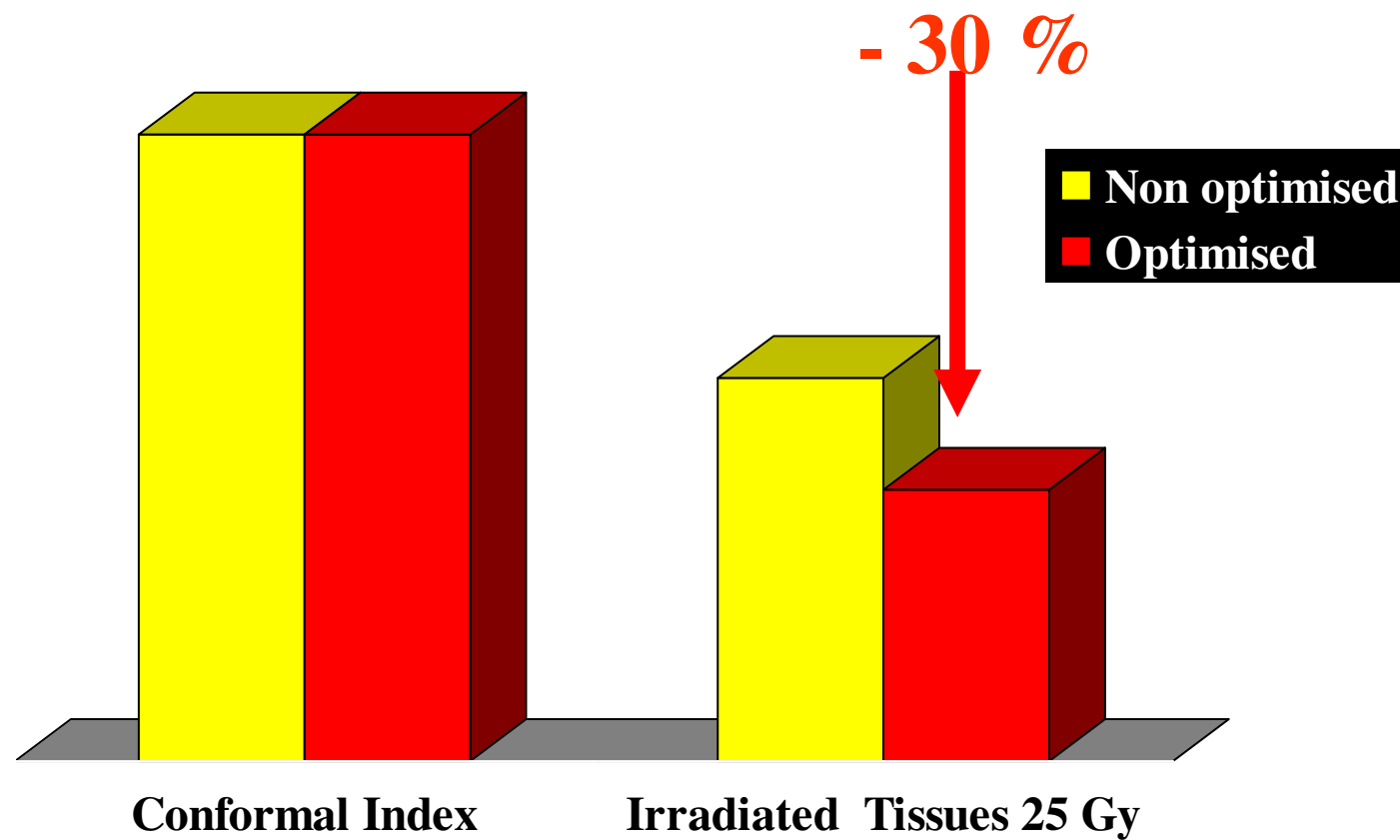


Non optimised



Optimised

To Optimise the treated volume Tonsil



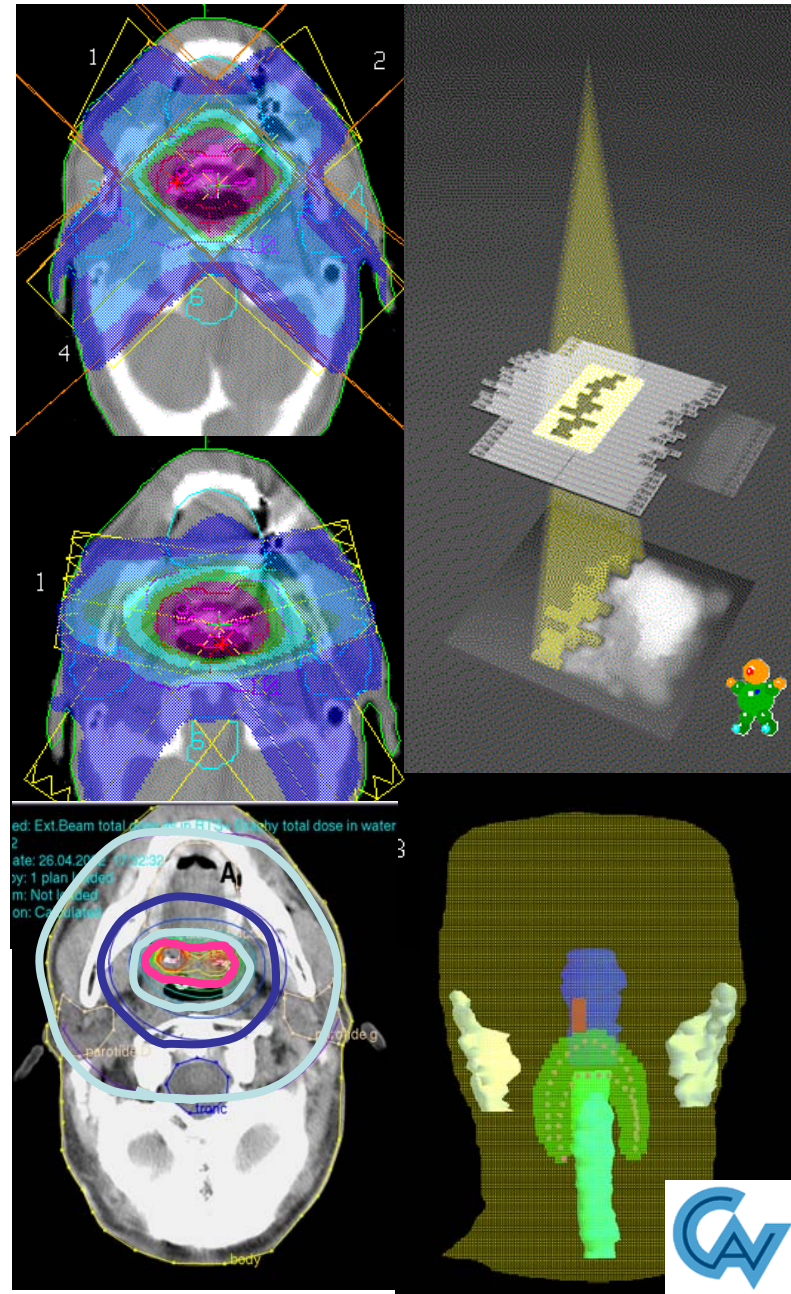
Ref: F. Ahmad, M. Lapeyre 2004

Brachy Versus IMRT?

3D-CRT

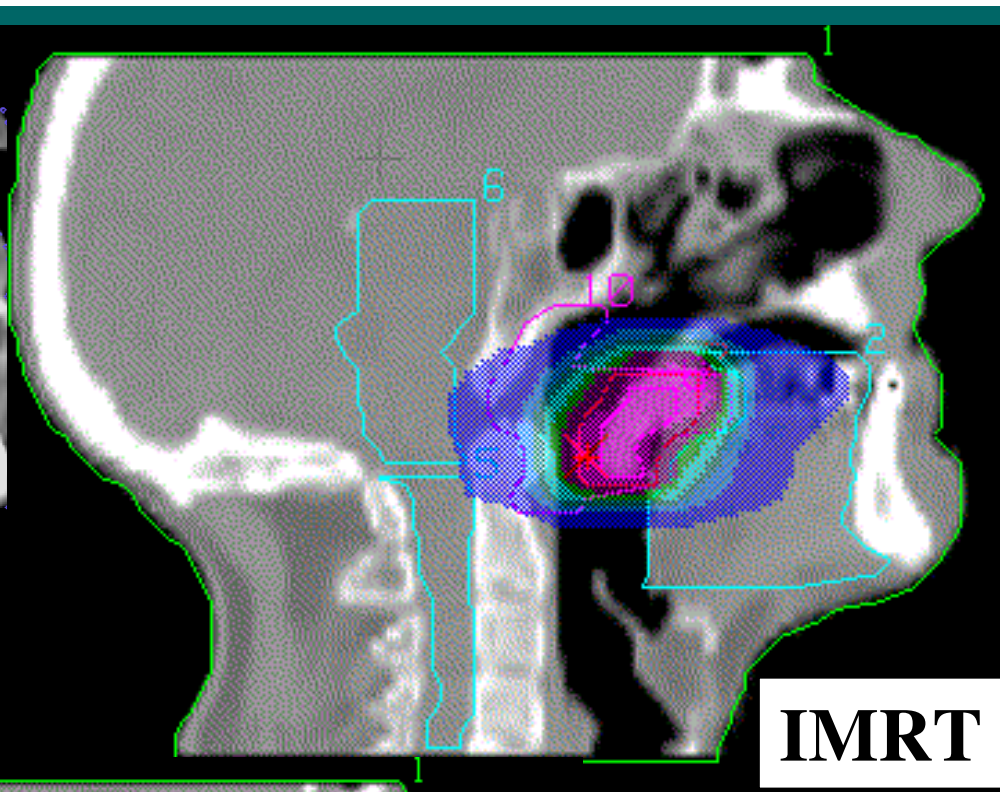
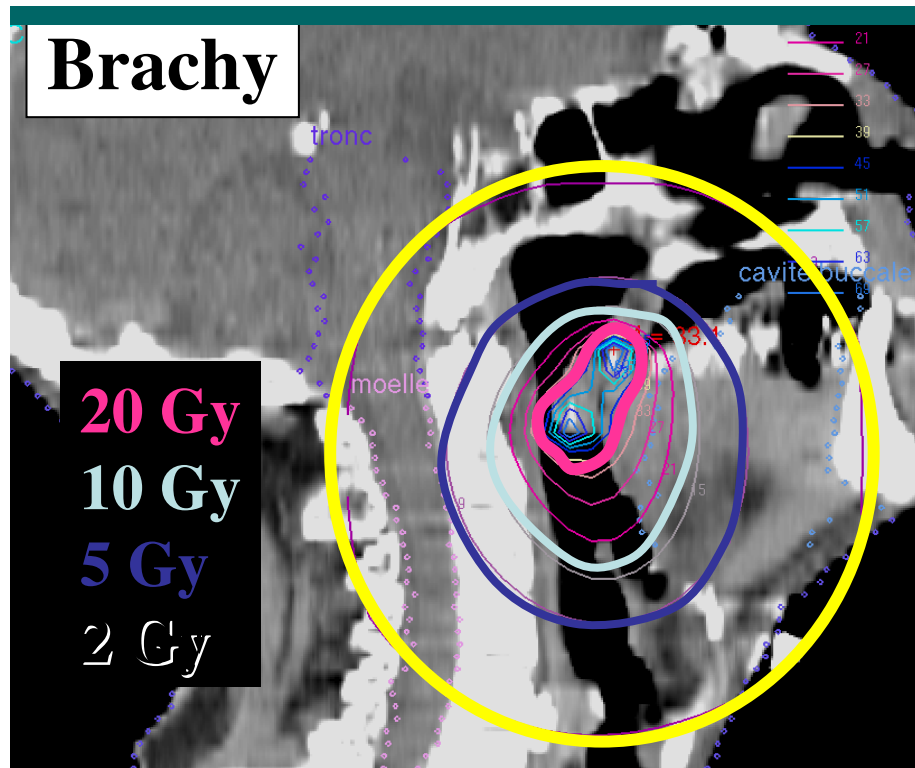
Dynamic IMRT

Brachytherapy



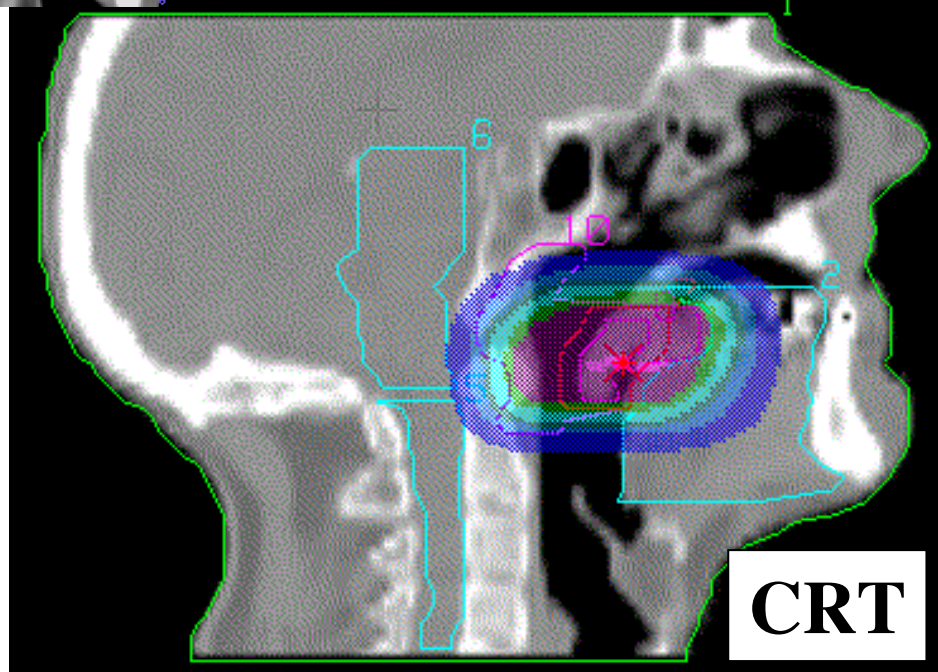
Brachy

20 Gy
10 Gy
5 Gy
2 Gy

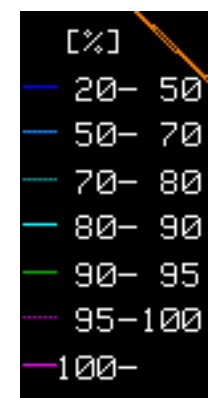


IMRT

Sagittal



CRT



Brachy Versus IMRT?

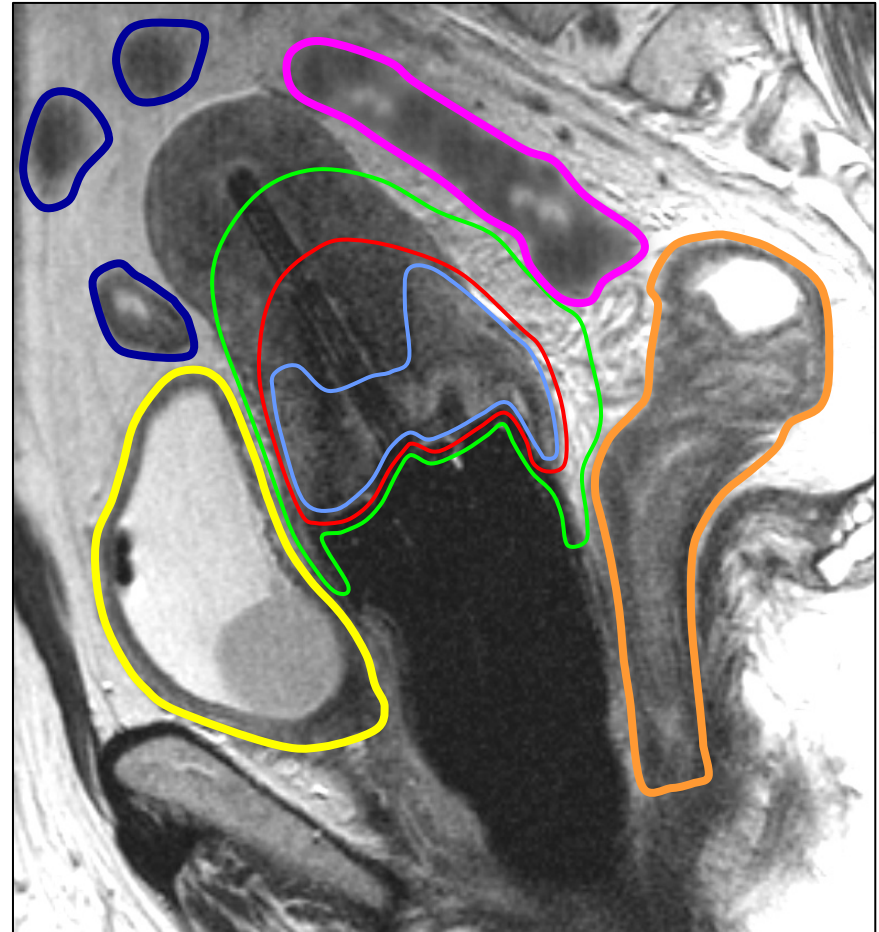
Cervix Brachytherapy

Dose escalation



**limiting
factors**

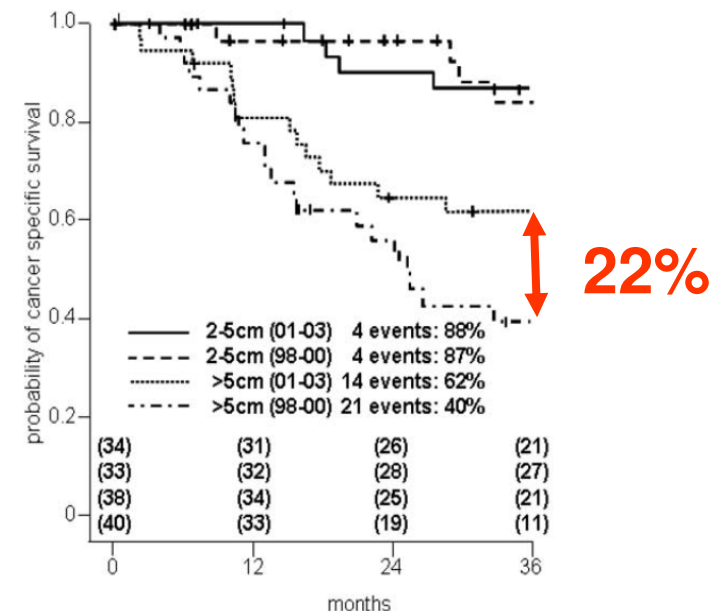
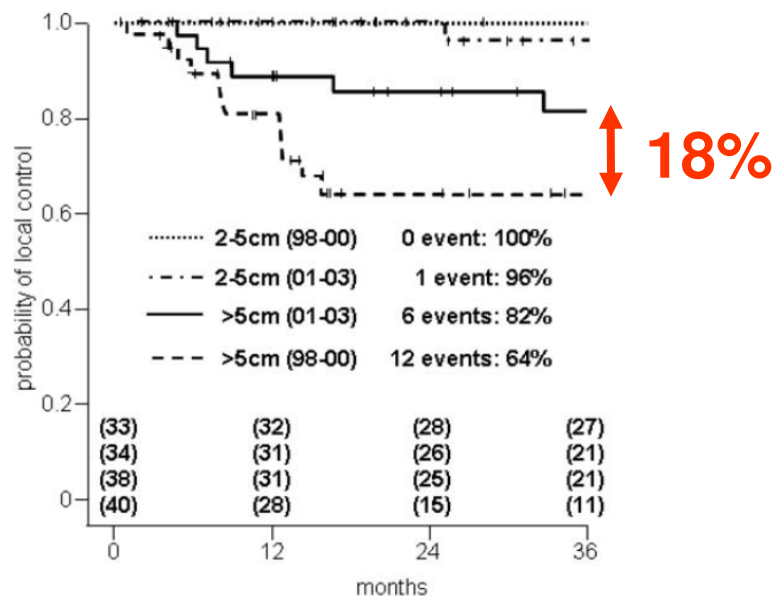
Doses to OAR





Clinical impact of MRI assisted dose volume adaptation and dose escalation in brachytherapy of locally advanced cervix cancer

Richard Pötter^{a,*}, Johannes Dimopoulos^a, Petra Georg^a, Stefan Lang^a,
Claudia Waldhäusl^a, Natascha Wachter-Gerstner, Hajo Weitmann^a,
Alexander Reinthaller^b, Tomas Hendrik Knocke^a, Stefan Wachter^a, Christian Kirisits^a

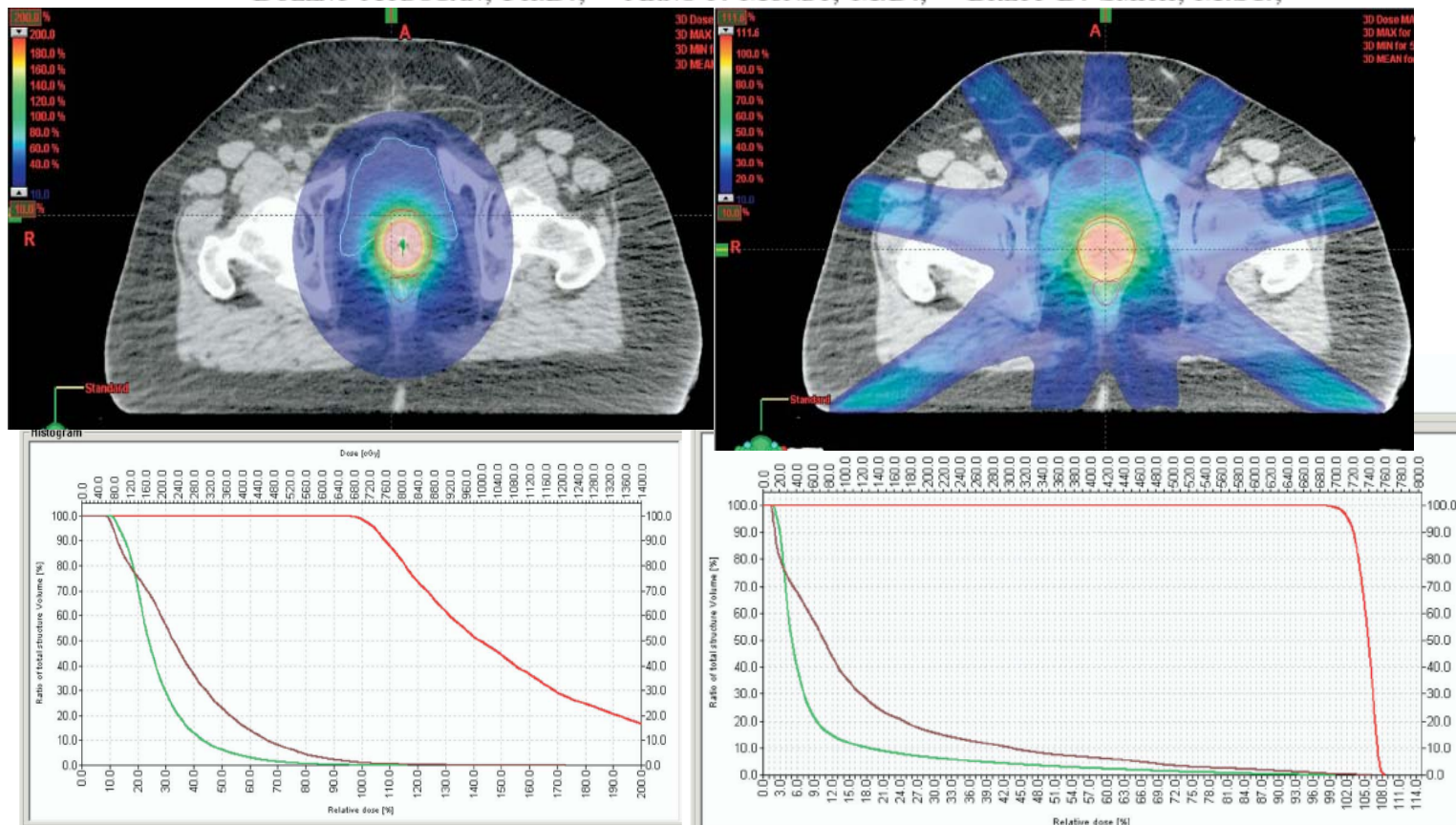


High is the temptation....

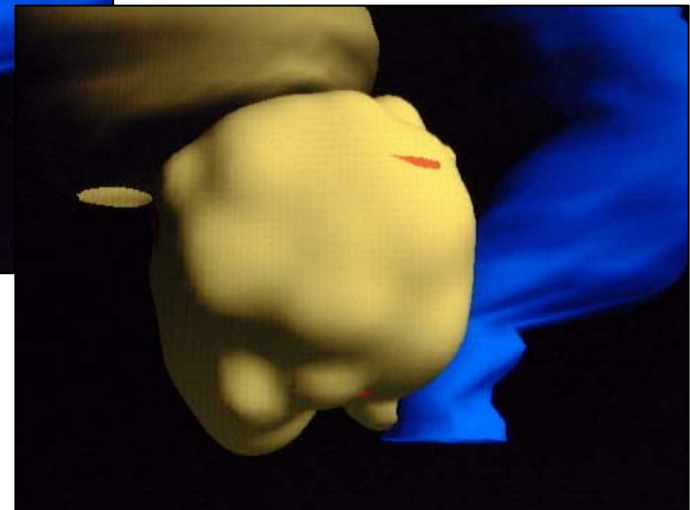
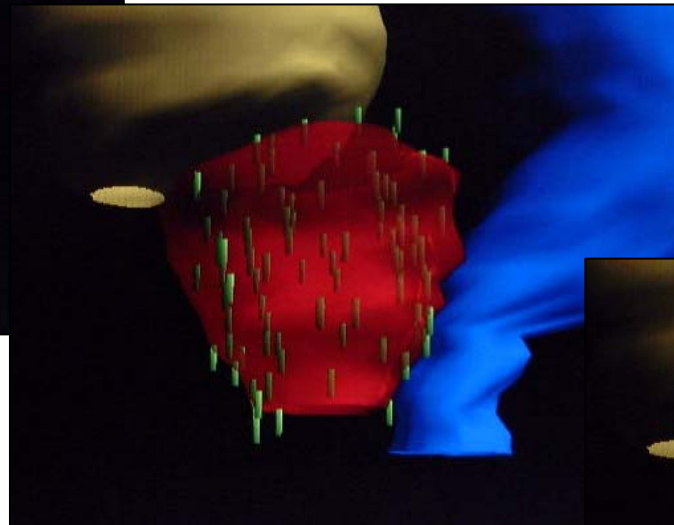
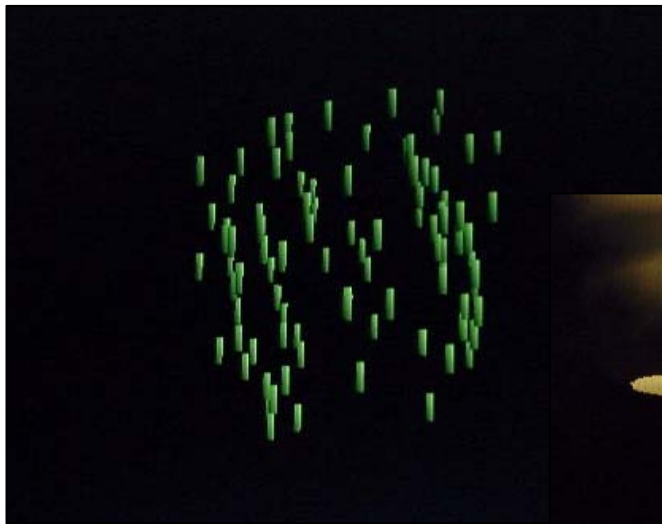
PHYSICS CONTRIBUTION

A DOSIMETRIC ANALYSIS OF INTENSITY-MODULATED RADIATION THERAPY (IMRT) AS AN ALTERNATIVE TO ADJUVANT HIGH-DOSE-RATE (HDR) BRACHYTHERAPY IN EARLY ENDOMETRIAL CANCER PATIENTS

BULENT AYDOGAN, PH.D.,*† ARNO J. MUNDT, M.D.,*† BRETT D. SMITH, M.Sc.,†



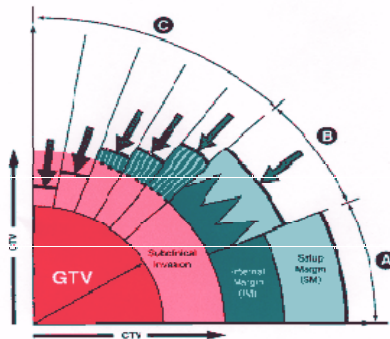
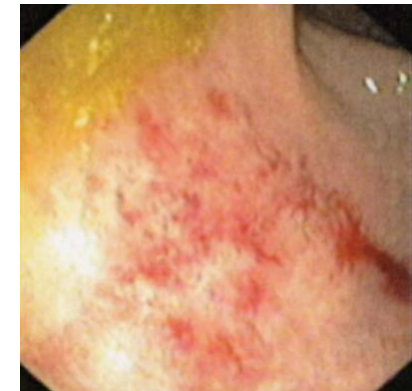
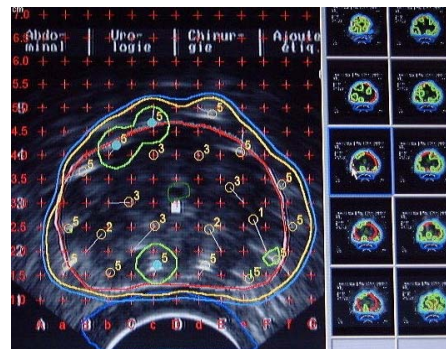
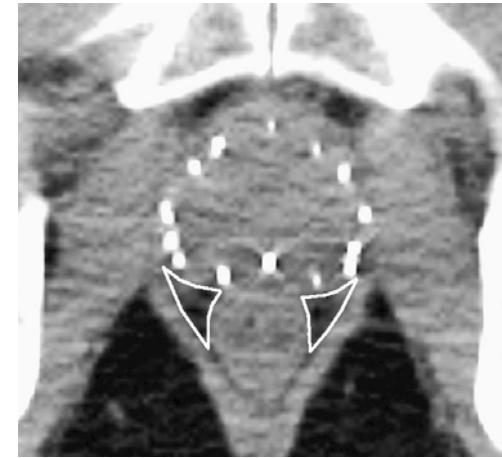
^{125}I Permanent implants



¹²⁵I Permanent implants

for low risk Prostate Ca

- Same results than Surgery or EBI
- Out patient procedure
- No incontinence
- No rectal bleeding
- Few erectile dysfunction



New Risks

- LDR techniques with low risks ?
- HDR and High tech with High risks ?

risk perception

Risk of overdosage ?
Risk of underdosage ?



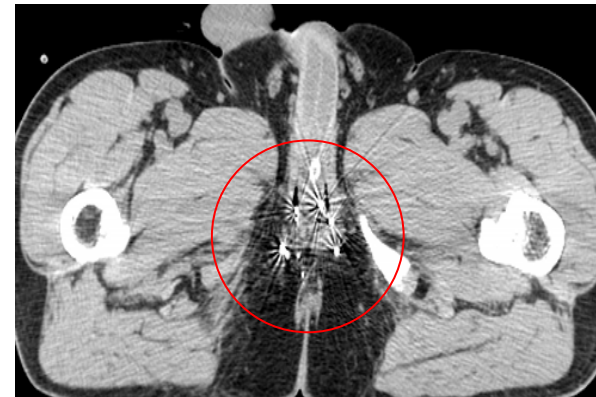
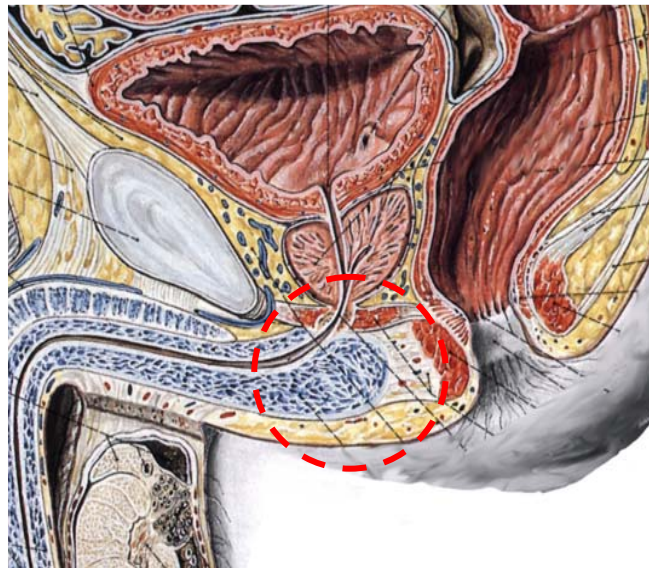


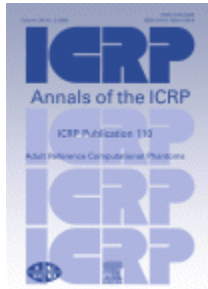
- Applicator insertion
- Dose computation
- Source preparation
- Source insertion
- Radiation protection
- Source removal



Same errors but different dose rate

- Misposition of the sources for a seed afterloader



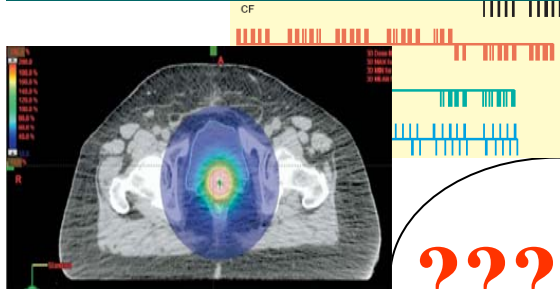


Recommendations of the International Commission on Radiological Protection

Working Group 53

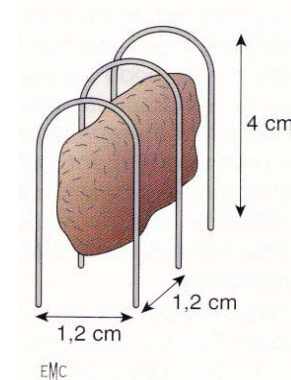
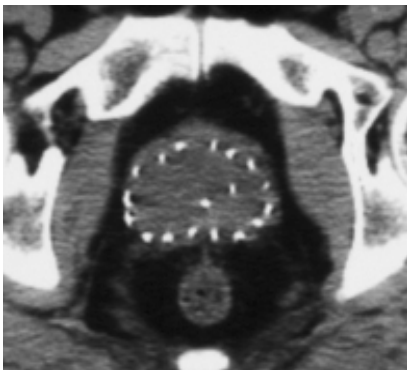
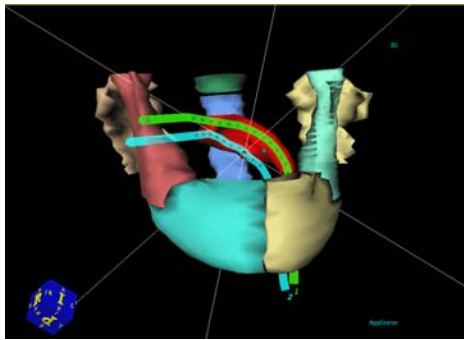
- HDR brachytherapy
 - ICRP Publication 97 (approved 2004)
 - Chairman: L Pinillos-Ashton
- Prostate implants
 - ICRP Publication 98
 - Chairman: J.M.Cosset

New risks



???????

DVH
Dose-rate/fractionation
Pronostic factors
High Tech



Brachytherapists use high technology and need a trained team

- QA program
- Proper Training
- Written protocols



No improvisation



International Conference on Modern Radiotherapy

Advances and Challenges in Radiation Protection of Patients

2 - 4 December 2009 - Versailles, France

www.conference-radiotherapy-asn.com

**Paradigms of external radiotherapy
and brachytherapy.
New techniques, new benefits and new risks**

“Advances in Brachytherapy”

Pr Didier Peiffert

Thanks to : Jack Venselaar, Jean Marc Cosset
Christine Haie-Meder ,Isabelle Barillot, Richard Potter for documents