

Principles of Interstitial Brachytherapy

27th August 2016

ICRO Teaching Course PUNE

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Presentation material contributed by members of Radiation Oncology & Physics Dept. of TMC

What will be covered

- What is brachytherapy
- Different types of brachytherapy
- Basic principles of brachytherapy in general and interstitial brachytherapy in specific
- Sources for Interstitial Brachytherapy
- Interstitial Brachy techniques & applications
- Dosimetry: Manchester – Paris – Modern
- Patient preparation and care during and after implant
- Radiobiology of brachytherapy
- Clinical outcome (complications & cure) in select sites

What is brachytherapy & its rationale

- Using sealed radioactive sources to deliver radiation to the tumour from a close distance or from within
- **Radiobiological Rationale:**
 - Interstitial and Intracavitary Brachy gives highest dose to the central part of the tumour with maximum clonogens / tumour density & also more of necrotic radio-resistant tumour
 - Short treatment time → Little or no repopulation
 - Volume Effect: Much less normal tissue Irradiated
- **Dosimetric rationale**
 - Ultimate form of conformal therapy
 - High doses in the CTV
 - Maximum sparing of adjacent critical/ normal tissue

Types of brachytherapy

Based on positioning of radionuclide

1. Intracavitary
2. Surface moulds
3. Intraluminal
4. Interstitial

Based on Dose rate

1. Low Dose Rate – LDR (0.4–2 Gy/h)
2. Medium Dose Rate – MDR (>2–12 Gy/h)
3. High Dose Rate – HDR (> 12Gy/h)

Total dose has to be reduced when dose rate increases & has to be fractionated

Based on technique

1. Pre-Loaded (mostly for permanent implants)
2. Manual after loading (now only for ICA in some centres)
3. Remote after loading (HDR or Pulsed LDR)
4. Intra / Peri / Post-Op or Radical implant with tumour in situ

Basic principles of brachytherapy

When do we consider it

In curative settings where

- Teletherapy or surgery has greater morbidity or less chances of cure
- Tumour (GTV) & its subclinical extension (CTV)
 - Is not too large
 - Is not too close to a critical normal structure
 - Is in an accessible site without major technical / operative challenges
 - Small volumes of surrounding normal tissues can tolerate modest to high doses of radiation
- Patient is Cooperative & motivated & is fit for anaesthesia & procedure
- Facilities and expertise for brachytherapy for such cases is available with good QA and clinical audit systems in place
- Long term clinical results show the clinical utility of brachytherapy

For each site there many External / Brachy Techniques (eg Breast APBI)

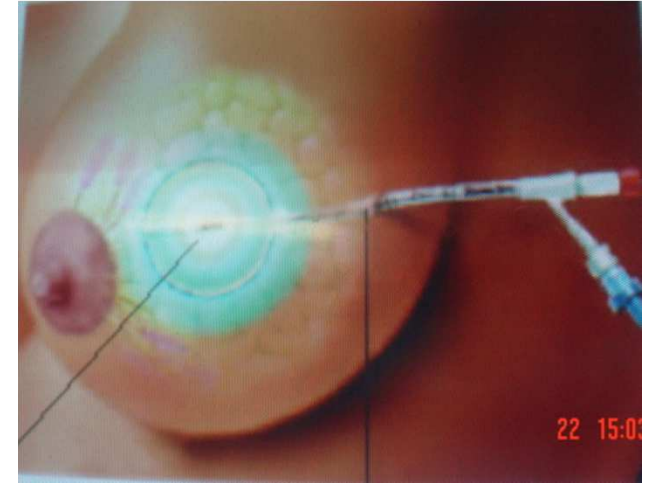
Interstitial



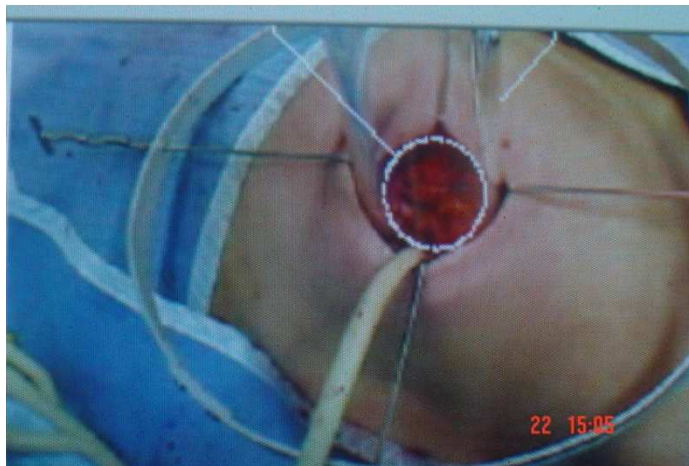
TARGIT



Mammosite

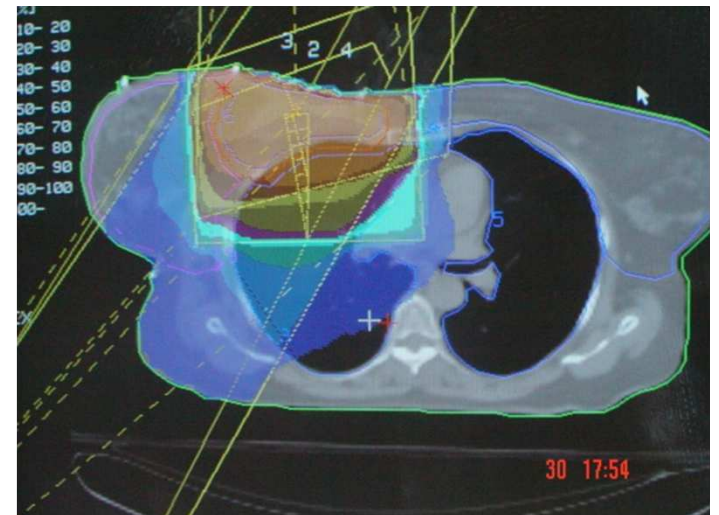


&
many
others



Electron Intra-Op RT [ELIOT]

R. Sarin



3DCRT / IMRT

SÉRIE A. N° 445

N° D'ORDRE

1127.

THÈSES

PRÉSENTÉES

A LA FACULTÉ DES SCIENCES DE PARIS

POUR OBTENIR

LE GRADE DE DOCTEUR ÈS SCIENCES PHYSIQUES.

PAR

M^{me} SKŁODOWSKA CURIE.

1^{re} THÈSE. — RECHERCHES SUR LES SUBSTANCES RADIO-
ACTIVES.

2^e THÈSE. — PROPOSITIONS DONNÉES PAR LA FACULTÉ.

Soutenues le juin 1903, devant la Commission d'Examen.

MM. LIPPMANN, *Président*.

BOUTY, } *Examineurs*.
MOISSAN, }

PARIS,

GAUTHIER-VILLARS, IMPRIMEUR-LIBRAIRE

DU BUREAU DES LONGITUDES, DE L'ÉCOLE POLYTECHNIQUE.

Quai des Grands-Augustins, 55.

R. Sarin 1903

THE USES OF RADIUM.

To the Editor of American Medicine:—It has occurred to me that perhaps you would care to publish the enclosed letters, and thus start some one experimenting with the radium rays in the manner suggested.

Z. T. SOWERS.

DEAR DR. SOWERS:

I understand from you that the Röntgen rays, and the rays emitted by radium, have been found to have a marked curative effect upon external cancers, but that the effects upon deep-seated cancers have not thus far proved satisfactory.

It has occurred to me that one reason for the unsatisfactory nature of these latter experiments arises from the fact that the rays have been applied externally, thus having to pass through healthy tissues of various depths in order to reach the cancerous matter.

The Crookes' tube, from which the Röntgen rays are emitted, is of course too bulky to be admitted into the middle of a mass of cancer, but there is no reason why a tiny fragment of radium sealed up in a fine glass tube should not be inserted into the very heart of the cancer, thus acting directly upon the diseased material. Would it not be worth while making experiments along this line?

[Signed]

ALEXANDER GRAHAM BELL.

[REPLY.]

DEAR DR. BELL:

The suggestion which you make in regard to the application of the radium rays to the substance of deep-seated cancer I regard very valuable. If such experiments should be made I have no doubt they would prove successful in many cases in which we now have failures.

[Signed]

Z. T. SOWERS, M.D.

15th August 1903

BRACHYTHERAPY

*Conquering Cancer
The First 100 Years*



BASIL S. HILARIS, M.D.

3rd Edition, 2014

Radium Institute devoted to the science of radioactivity established in 1912 in Paris

Curie Pavillion (Marie Curie): Research in Chemistry & Physics

Pasteur Pavillion (Claude Regaud): Research in biology & medicine



Radium Institute

In early 20th century many cancer hospitals established in Europe & USA
and named **Radium Hospitals or Radium Centres**

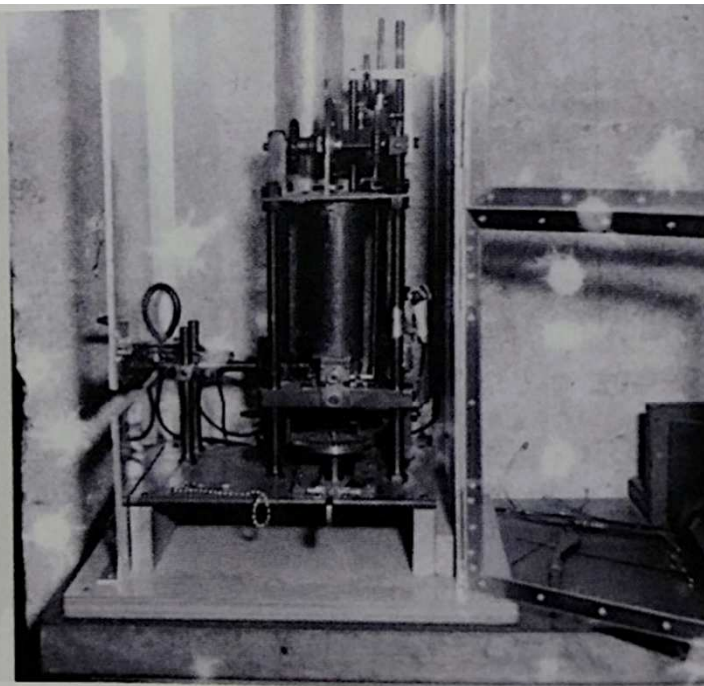
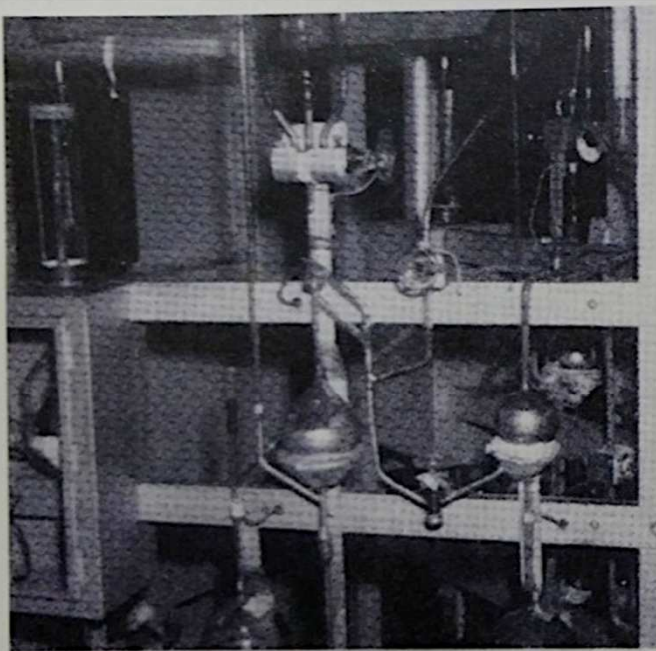
RANCHI LINGO

the story behind local *Places*



RADIUM ROAD (रेडियम रोड)

Radium being a radioactive material, its radiation were once used to treat cancerous cells in the body. There used to be a centre for the same around Kutcheri to Ranchi University road, thus it got the name **Radium Road**.

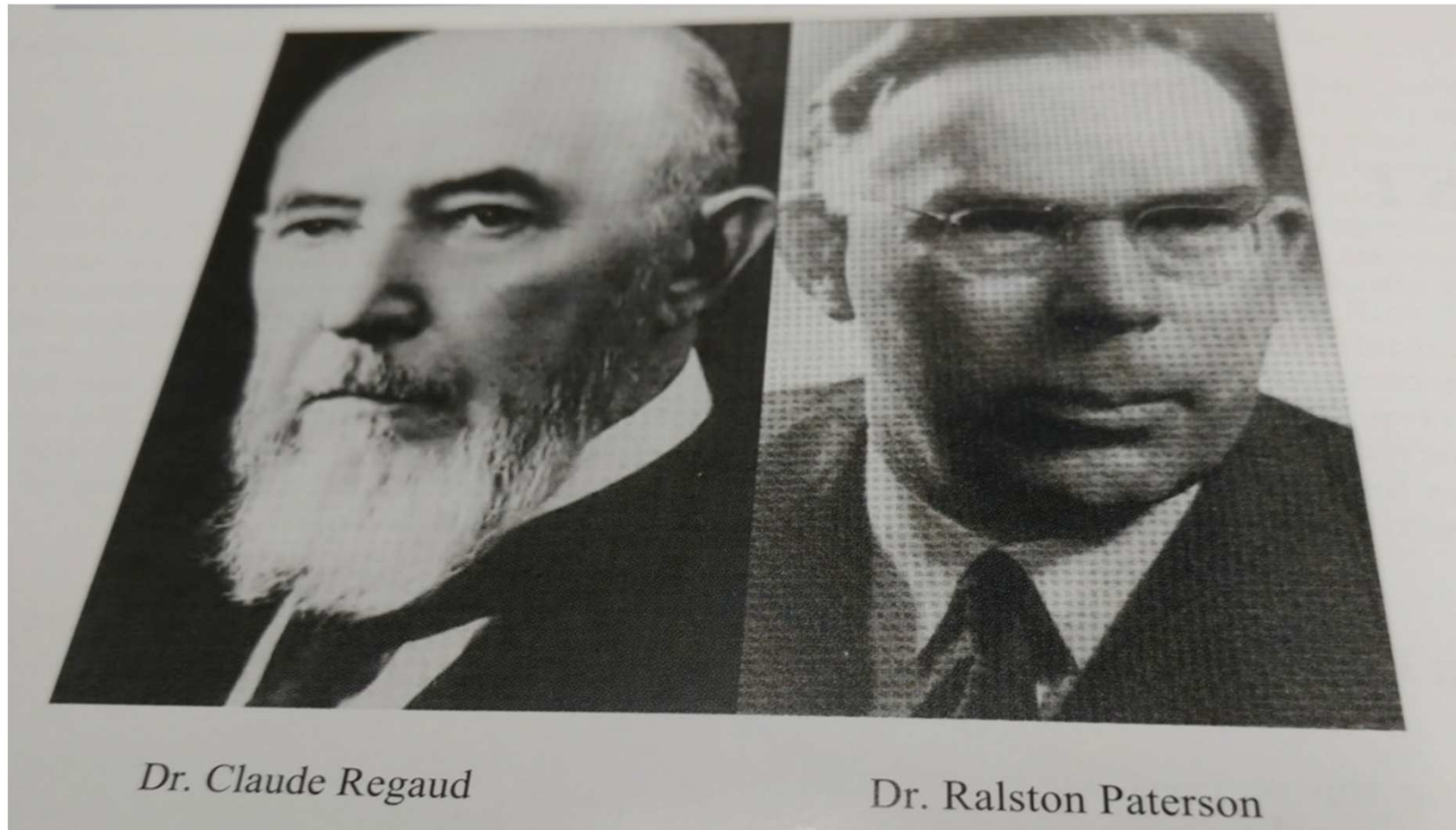


On the left: The pumping apparatus which produced the gold (radon) seeds.
On the right: The seeds were sorted according to their activity with this automatic apparatus.



The radon seeds were loaded in each needle in the operating room, prior to their insertion.

1st Radon Plant in India in Tata Hospital (1942)

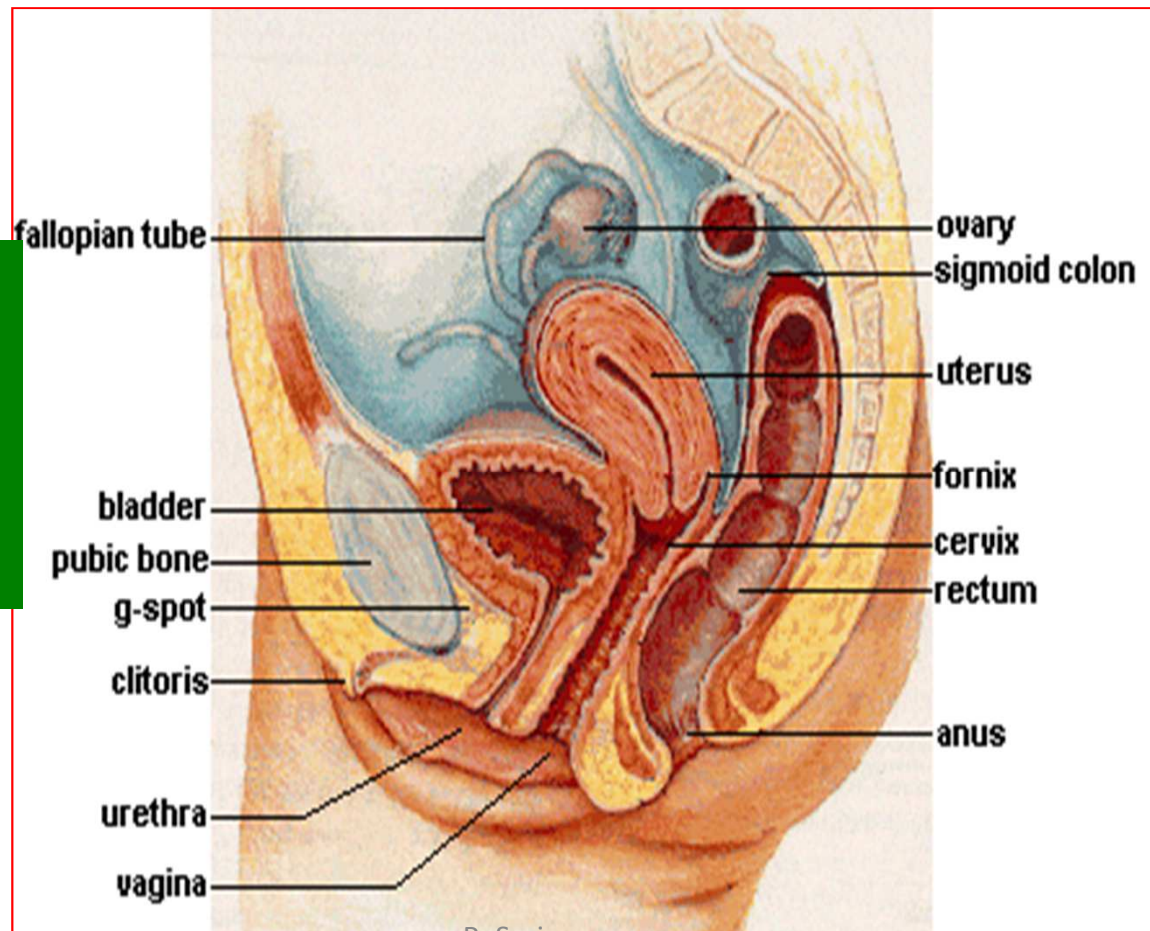


Radium Institute, Paris
Biology of Curietherapy

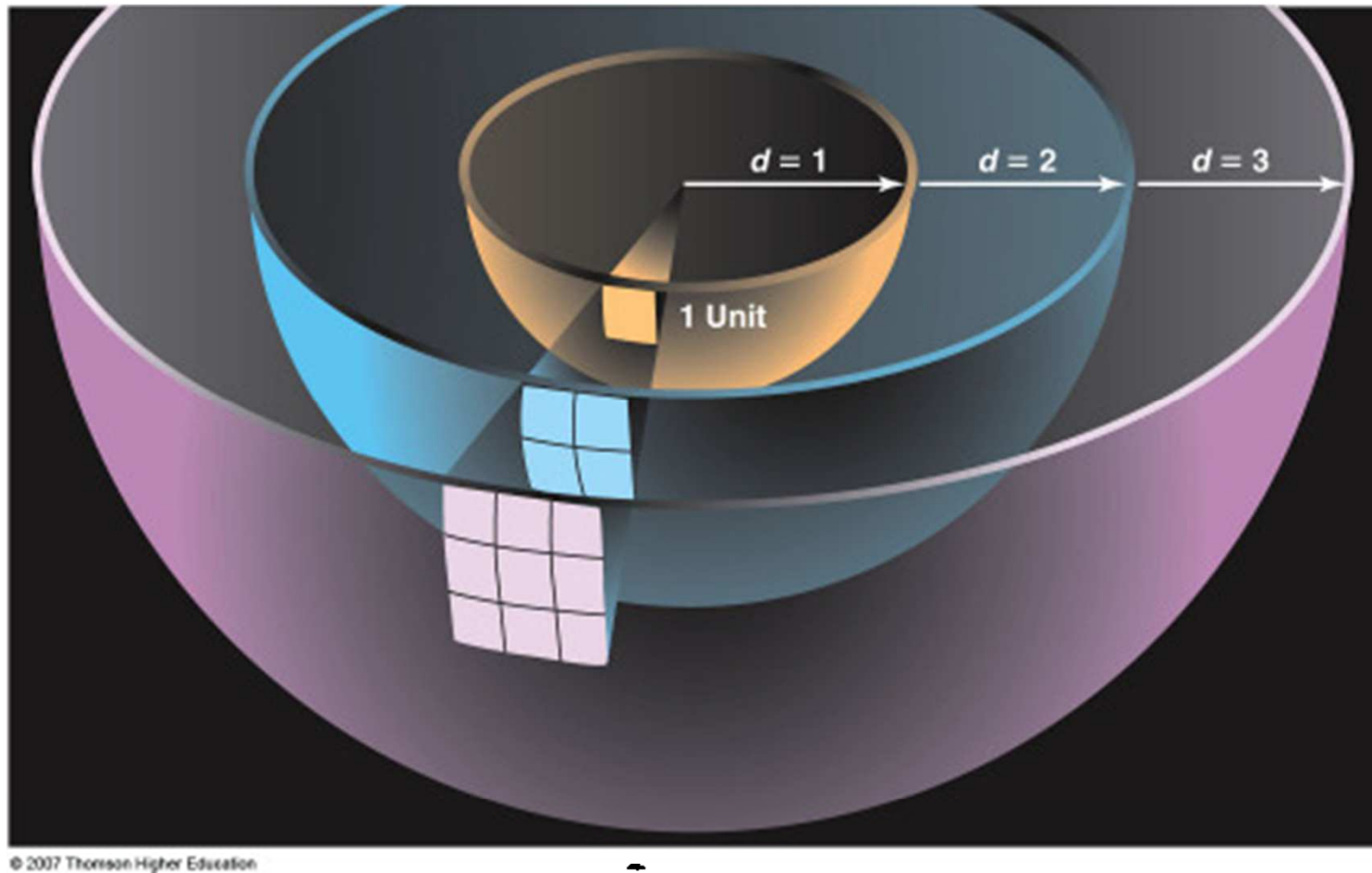
Radium Institute, Manchester
Dosimetry of Curietherapy

Brachytherapy has shown best benefit for Cancer Cervix due to its unique anatomy, permitting placement of sources within and around it

*What
else ??*



The Inverse Square Law



$$I = \frac{E}{4\pi d^2} \quad \text{or} \quad I \propto \frac{1}{d^2}.$$

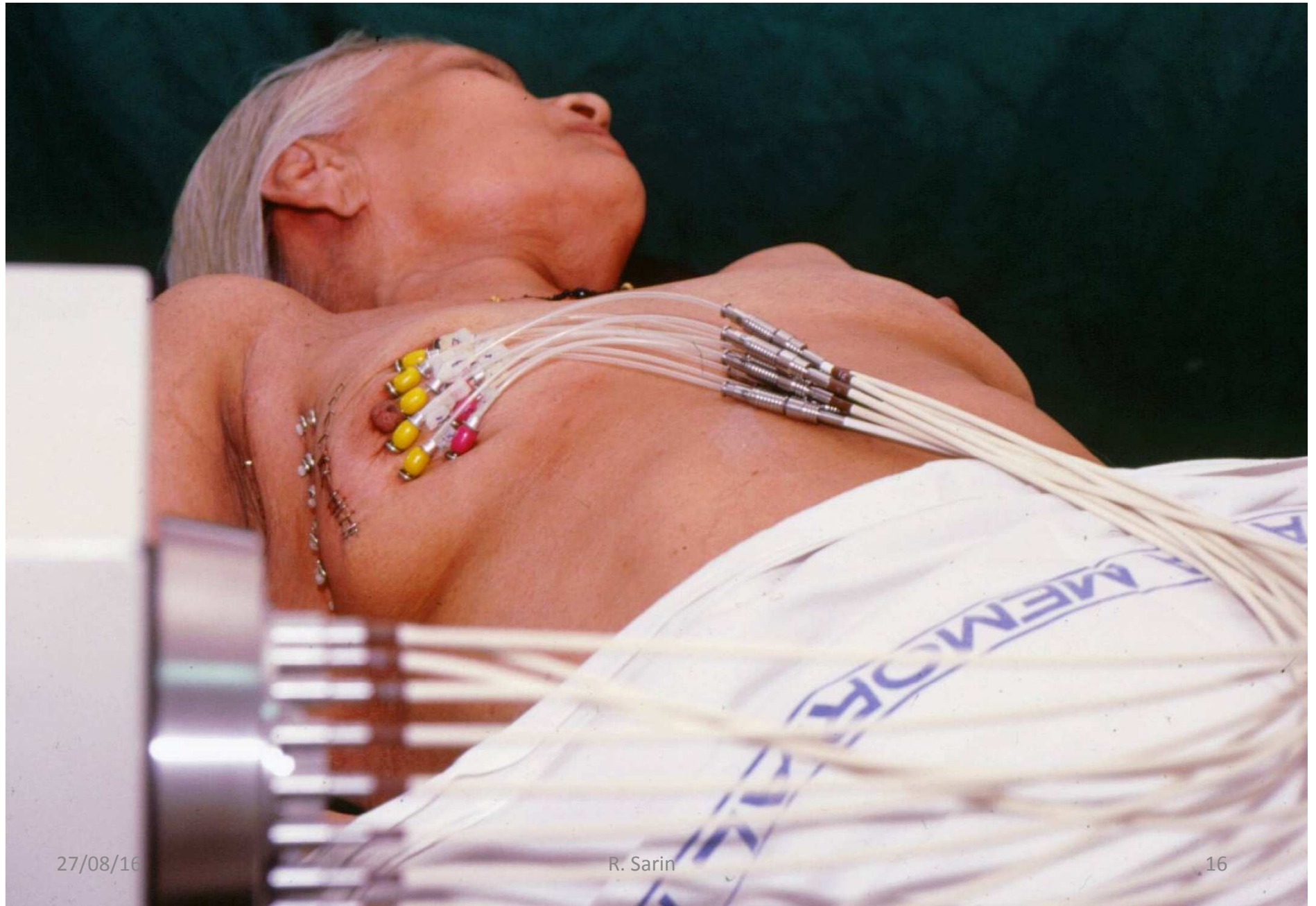
One two ka four

27/08/16

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Interstitial Brachytherapy implant connected to HDR machine



DEFINITIONS

- **Radioactivity:** Disintegrations per unit time (sec ,min, hrs)
 - 1 curie (ci)= 3.7×10^{10} disintegration /sec
 - 1 Becquerel (Bq) =1 disintegration / sec. (SI unit)
- **Half life($T_{1/2}$):** Time to lose half of its original activity
- **Half Value layer (HVL):** “Thickness of the specified substance that reduces the exposure rate at point of measurement by half
- **Exposure Rate:** Ionization equivalent of the KERMA in air
- **Specific Gamma-Ray Constant:** Exposure rate per unit activity at a certain distance from a source.
 - The SI unit: $C \text{ kg}^{-1} \text{ s}^{-1} \text{ Bq}^{-1}$ at 1 m
 - Traditional unit: $R \text{ hr}^{-1} \text{ mCi}^{-1}$ at 1 cm

Specification of the Source “Strength” (Intensity)

- ICRU 38 & 58 recommends that the brachytherapy source strength (intensity) should be specified in terms of the quantity “**Reference Air Kerma Rate**” (**RAKR**)
- **RAKR** is the AIR-KERMA rate, in vacuo, at a Reference distance of 1 meter from source centre in its transverse axis from photons of $> \delta$ (**delta**) energy
- **Unit:** Gy s⁻¹ at 1 meter (For LDR: $\mu\text{Gy h}^{-1}$ at 1 m)
- **Energy cut-off (δ)** excludes low-energy photons (e.g., characteristic x rays originating in the outer steel or titanium source cladding) that can significantly increase RAKR without contributing much to absorbed dose beyond 1mm
- **Air KERMA Rate Constant Γ_δ :** The physical quantity which governs the relation between RAKR & other quantities used to specify the source (unit Gy/s at 1M)
- For gamma point sources, Γ_δ is the kerma rate, at reference distance of 1 meter / unit activity, from photons of energy greater than δ in vacuo
- For gamma energies of sources used in brachytherapy, one may consider that the numerical values for dose and KERMA are equal
- For beta sources - Absorbed Dose Rate at 2 mm from the source centre

Brachytherapy sources are specified in terms of their “output” (dose rate) at reference distances / in different conditions. “Activity” used only for regulatory & protection purposes

Total Reference Air Kerma – TRAK

Sum of the products of the
Reference Air Kerma Rate & irradiation time for each source

- Unambiguous quantity simple to calculate (if source strengths in RAKR)
- Conversion mg.h to TRAK is easy: 1 mg.h radium equivalent (0.5 mm Pt filtration) corresponds to 7.2 μ Gy at 1 m.
- The doses to all organs & integral dose directly proportional to the TRAK
- TRAK indicates the absorbed doses delivered during treatment at distances from the sources down to 20 - 10 cm (i.e., in the pelvis or abdomen). The dose at 10 cm from the centre of the sources is roughly 100 times higher than the TRAK. However TRAK does not even approximately indicates absorbed dose near the source (i.e. tumour or target volume).
- TRAK, or the sum of the RAKR of all sources, can serve as a useful index for radiation protection of the personnel and nursing staff in charge of the patient (kerma -or dose- rate at 1 meter from the patient, neglecting, as a first approximation, the attenuation and scattering phenomena)

IDEAL BRACHYTHERAPY SOURCE

- IDEAL: Infinitely small, isotropic, un-encapsulated, mono-energetic gamma ray of $\sim 200\text{KeV}$ with long half life & exact source activity is known
- Available 'Nearly Ideal' sources have
 - Finite size
 - Encapsulated
 - Often emit a spectrum of beta and gamma rays from few KeV to 2MeV
 - Source activity is known only approximately
 - Anisotropic emission due to the size, design, encapsulation of source. Self attenuation / scattering within source material, sheathing, applicator, tissues

Properties of an IDEAL brachytherapy source in practice

- Gamma ray energy 0.2-0.4MeV
 - High enough to avoid energy deposition in bone by photo-electric effect.
 - Low enough to minimize need for radiation protection.
- Half life such that correction for decay during Rx is minimal
- Absent / easily screened charge particle emission

Some examples

- High specific activity eg. ^{192}Ir
- No gaseous disintegration product eg. radon
- Insoluble & non-toxic
- Not in powder form eg. Radium sulphate
- Can be made in different shapes eg. ^{192}Ir
- Permanent Implants- $t_{1/2}$ should be short

Types of Radioisotopes depending upon type of emission

γ emitters : ^{226}Ra , ^{222}Rn , ^{60}Co , ^{137}Cs , ^{192}Ir , ^{125}I ^{198}Au ,
 ^{103}Pd , ^{169}Yb , ^{145}Sm , ^{241}Am .

β emitters : ^{32}P , ^{90}Sr , ^{90}Y , ^{106}Ru , ^{49}V , ^{166}Ho , ^{144}Pr

neutron emitter: ^{252}Cf

RADIUM

- Earliest & once the most commonly used isotope
- $T_{1/2} = 1626$ yrs
- γ rays from Ra & its decay products of energy- ranging from 0.184 MeV - 2.45 MeV (avg. 0.83 MeV)
- β filtration : 0.5 mm of Lead/ platinum
- Widely used for all kinds of brachytherapy
- Radium sulfate/Ra chloride mixed with inert filler & loaded in cell (1cm long & 1mm in dia. made of 0.1-0.2 mm thick Gold foil)



Radium became OBSOLETE after 75 years of glorious history because of

- Risk of leakage of radioactive salt / Radon gas
- Difficulty in Disposal
- Specific activity low
- Mixture of several intermediate radioactive products-dose calculation error can occur.
- **Better Radium substitute became available**

After major developments in Teletherapy and increased recognition of hazards of using Radium, the use of brachytherapy started declining from 1960s

Renaissance of Brachytherapy started with

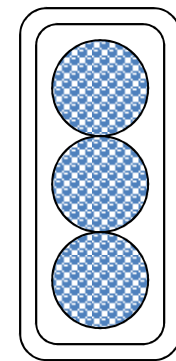
- Newer isotopes (Iridium-192, I-125 and others)
- After-loading systems
- Higher dose rate systems
- Computerized optimized planning & dose delivery

Radioactive sources: Past, present and future

Application	Traditional	Current	Future
Intracavitary LDR HDR	<u>Ra226</u> Co60	<u>Cs137</u> Ir192	Am241, Ir192, <u>Yb169</u> Yb169, Ir192, <u>Co60</u>
Interstitial Pre-Loaded After loading HDR	Ra226 --- ---	Cs137 <u>Ir192</u> Ir192	-- I125, Pd103, Yb169 Yb169, Ir192
Permanent implant Conventional dose-rate Ultra low dose rate-	Rn222 --	Au198 <u>I125</u> Pd103	Au198, <u>Cs131</u> I125, <u>Pd103</u>

CESIUM 137: (Cs^{137})

- $T_{1/2}$: 30 yrs
- Relatively cheaper, extraction simple,
- No gaseous decay product, safer than Ra
- γ ray energy = 0.662 MeV
- Beta filtration – 0.5 mm Pt or stainless steel
- Available in tubes, needles, pellets.
- Replaced Radium for cancer cervix.



Miniature cylindrical source

IRIDIUM 192 (^{192}Ir)

- **T_{1/2} = 73.8 days**
- **γ ray energies (0.136 to 0.613 MeV)**
- **Effective γ rays energy approx 0.380 MeV**
- Emits β particles max energy 0.670 MeV
- β filtration = 0.1mm of platinum
- (Eliminated by stainless steel capsule)
- HVT- 4.5mm of Lead (Pb)
- **Flexible nylon strands / platinum clad wire**
- **Miniature high activity source – HDR Brachy**

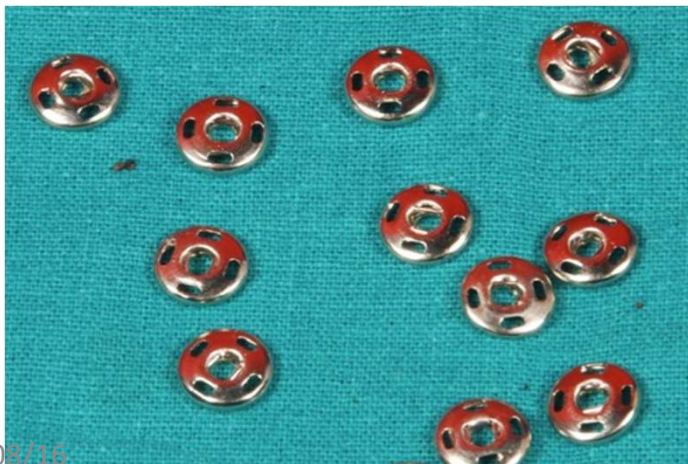
IODINE(^{125}I)



- Used in permanent implants & can also be used in removable implants.
- $T_{1/2} = 59.6$ days
- Decays by Electron Capture to Tellurium – 125 which decays immediately by Gamma Decay with Max energy of 35KeV
- Adv over Rn & Au –longer $t_{1/2}$
 - convenient for storage
 - low photon energy, less shielding .

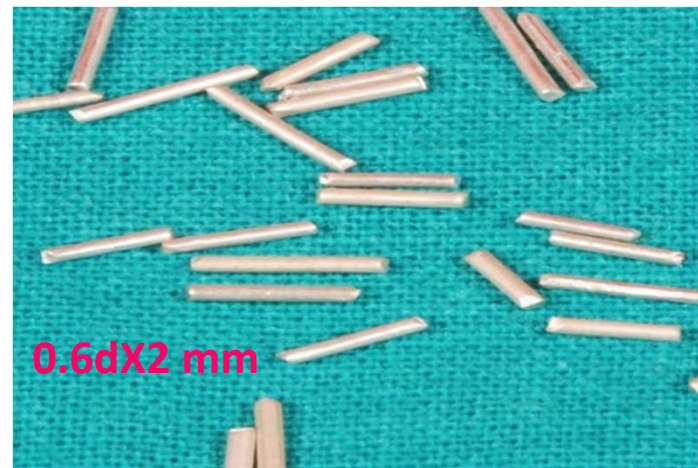
But- dosimetry is much complex

Brachytherapy Accessories



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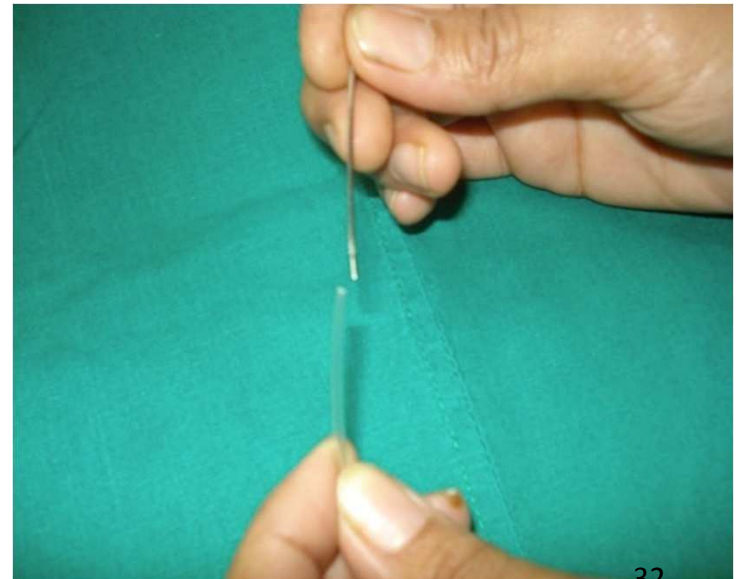
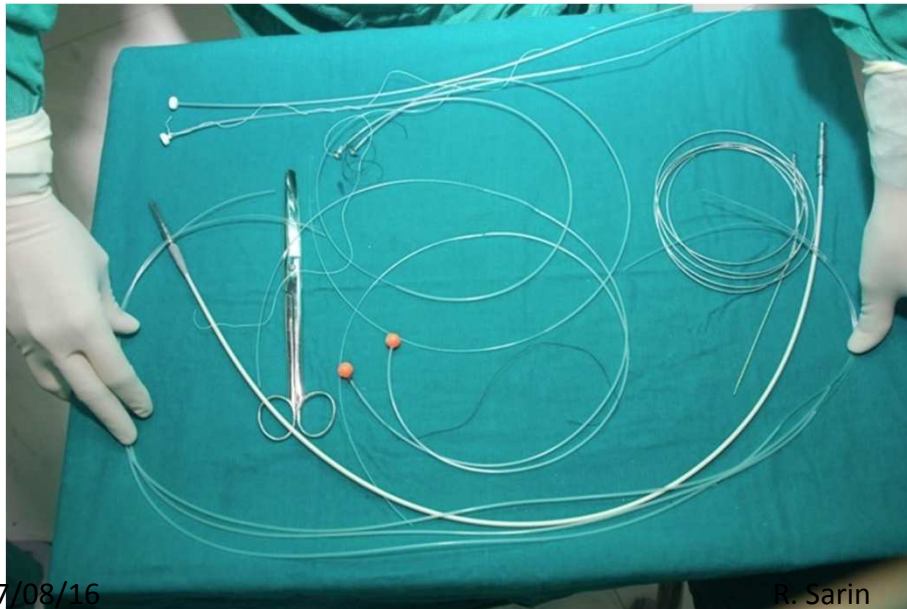
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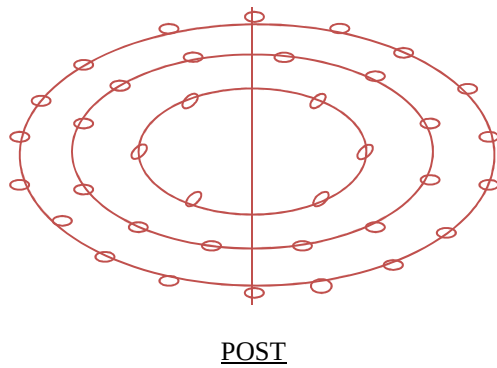
Brachytherapy Accessories, Nylon catheters cont...

- Check the inner and outer diameter of the catheters with the Transfer tube of Selectron HDR before sending to OT

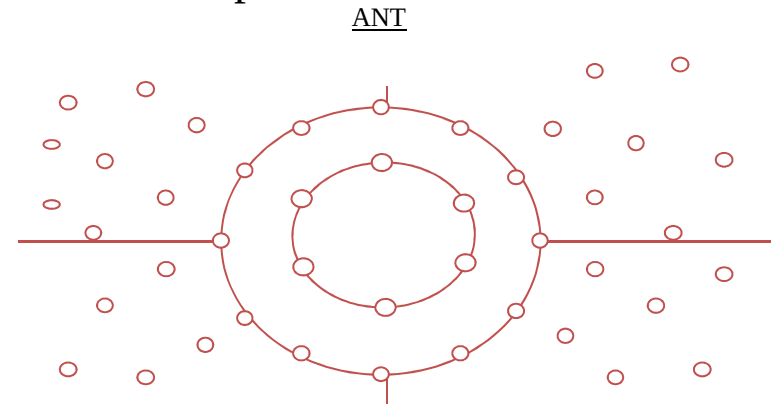


Different kinds of Templates

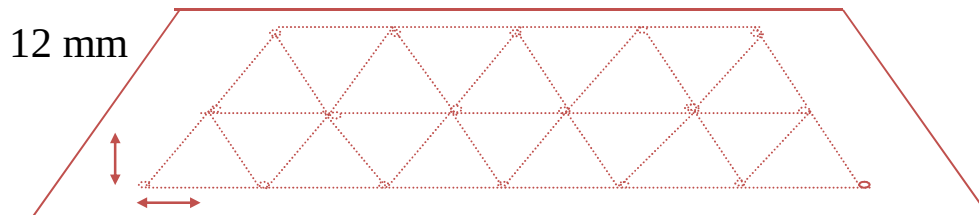
Anal Canal/Prostate template



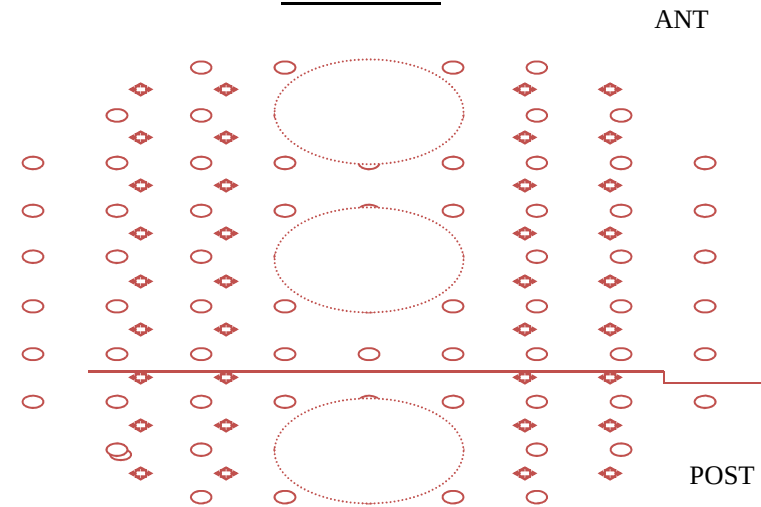
GYN template



Breast Template



MUPIT



St. needle

◈ Ang. needle

For each interstitial brachytherapy case we need to know

- The Gross Tumour Volume (GTV)
- Clinical Target Volume (CTV) for subclinical spread
- Unlike Teletherapy, PTV concept usually not relevant
- Any dose limiting normal structures in the vicinity
- What anatomical constraints and normal structures (e.g. vessels, lung) may come in the path of the needles
- Which sources and applicators are available
- What dose rate, imaging & optimization methods available
- Will it need planar or volume implant (how many planes)
- How to orient the implant – entry and exit site
- What geometry is likely to be best suited
- Are there ways to improve geometry (Template, imaging etc)
- Appropriate and evidence based dose / fractionation
- Patients likely tolerance of the procedure & treatment





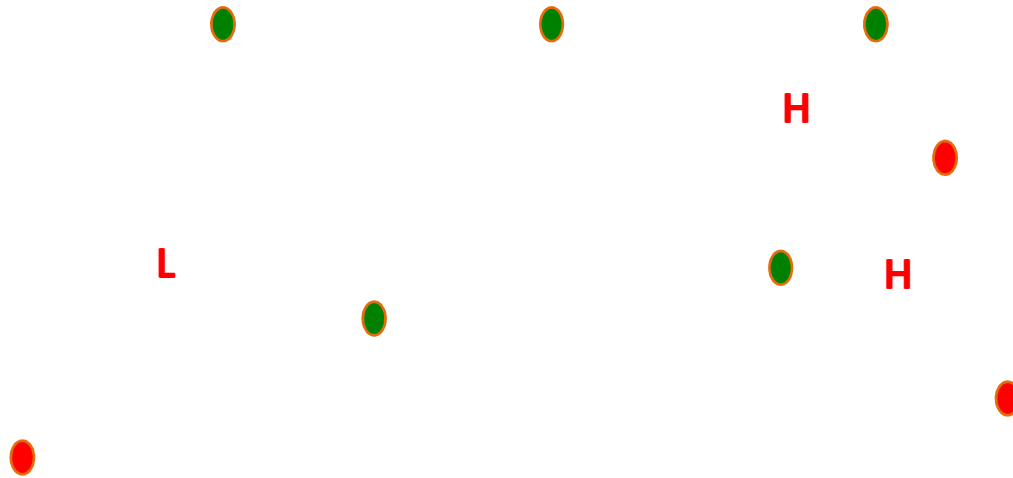
ICRU 58 for interstitial brachytherapy

- **Prescribed dose:** Dose which the Radiation Oncologist intends to give and writes in the patients chart
- **Treated volume:** Volume of tissue encompassed by the isodose selected and specified by the Radiation Oncologist as appropriate for that implant.
- **Minimum Target Dose (MTD)** is the dose at the periphery of CTV (minimum peripheral dose). It 'should be' the dose decided by clinician as adequate for treating the CTV. MTD is 90% of the prescribed dose in Manchester system
- **Mean Central Dose (MCD):** Arithmetic mean of the minimum doses between sources in the central plane
- **High Dose Volumes (HDV):** Volumes encompassed by the isodose corresponding to 150% of the mean central dose. Large HDV / Hyperdose sleeve predicts late toxicity
- **Low Dose Volumes (LDV):** Volume within the CTV encompassed by the isodose corresponding to 90% of prescribed dose. It predicts geographical miss & local recurrence

ICRU 58 for interstitial brachytherapy

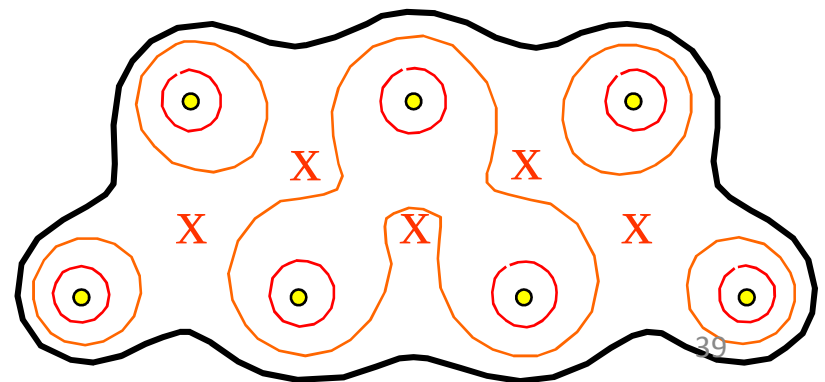
- **Dose Uniformity Parameters**
 - **Dose Homogeneity Index (DHI):** Ratio of minimum target dose to the mean central dose (MTD/MCD)
(In RTOG 0413 APBI DHI is : $(V100\%-V100\%)/V100\%$
e.g. $(90-20)/90 = 0.78$ {Desirable DHI >0.75 })
 - The spread in the individual minimum doses used to calculate the mean central dose in the central plane expressed as a percentage of the mean central dose
- DVH to generate quality indices of implant
- Implant quality depends on Geometry & strength of sources in relation to the CTV
- **Time / Dose Pattern:** Continuous LDR temporary & permanent & fractionated HDR

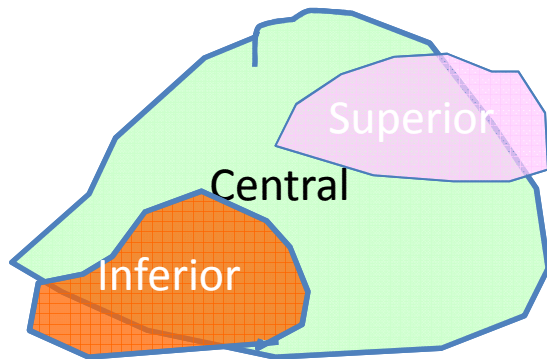
What we want to achieve (but what may happen)



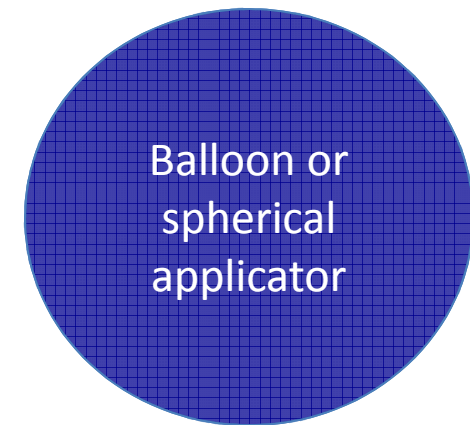
Dose Optimization by changing the Dwell position & Dwell Time

Can improve dose distribution to some extent
It can compensate for slightly sub-optimal geometry
BUT CANNOT TAKE CARE OF BAD IMPLANT



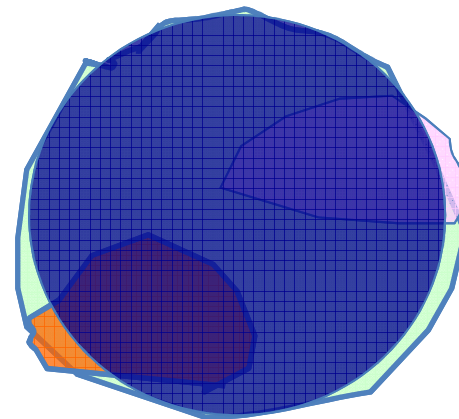


Lumpectomy cavity



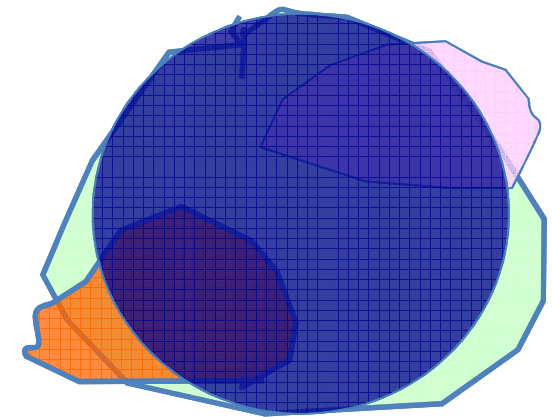
Is the higher local recurrence rates with TARGIT / ELIOT due to very low energy 50KV Xrays or inadequacy of 4-5 cm diameter sphere or flat electron applicator to adequately cover a larger cavity

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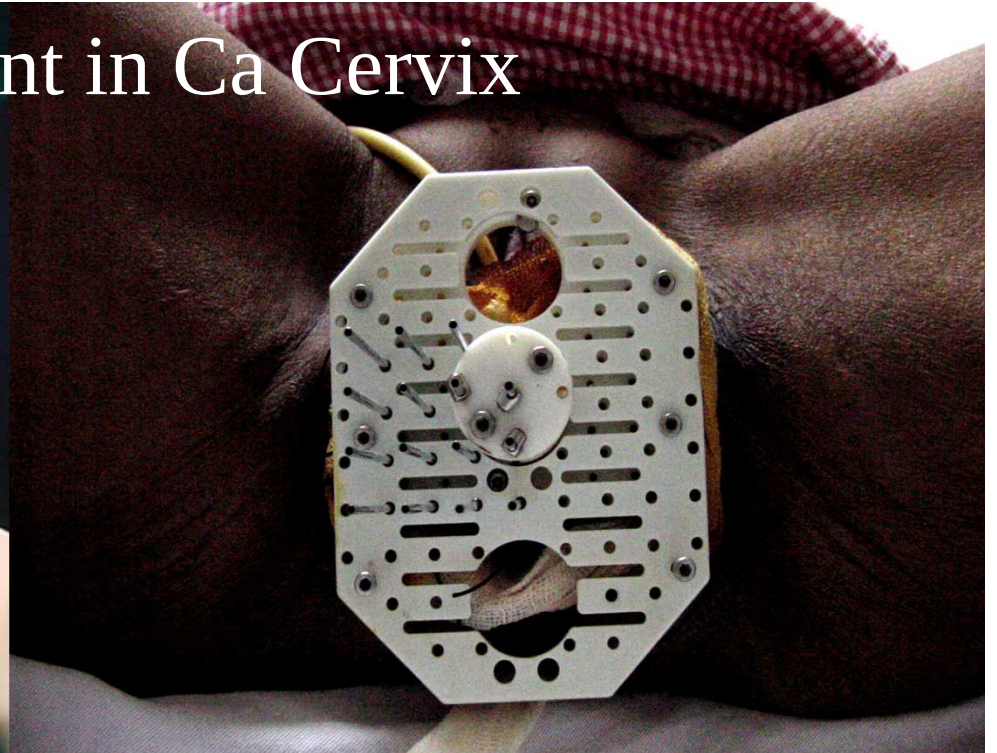
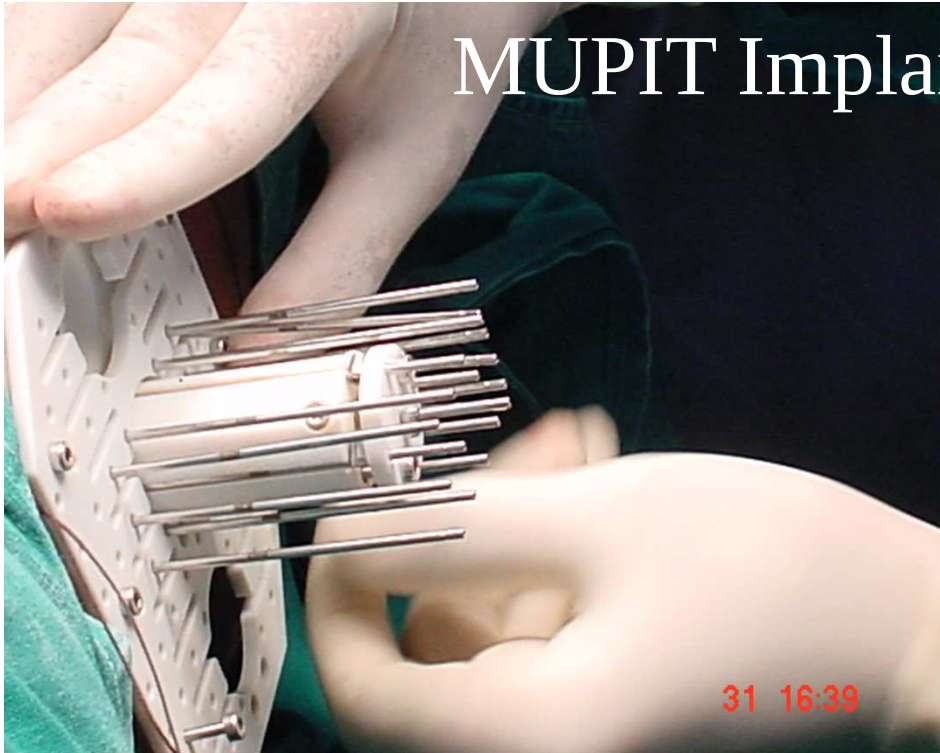
Small cavity well covered by standard applicator

Large cavity NOT adequately covered by standard applicator

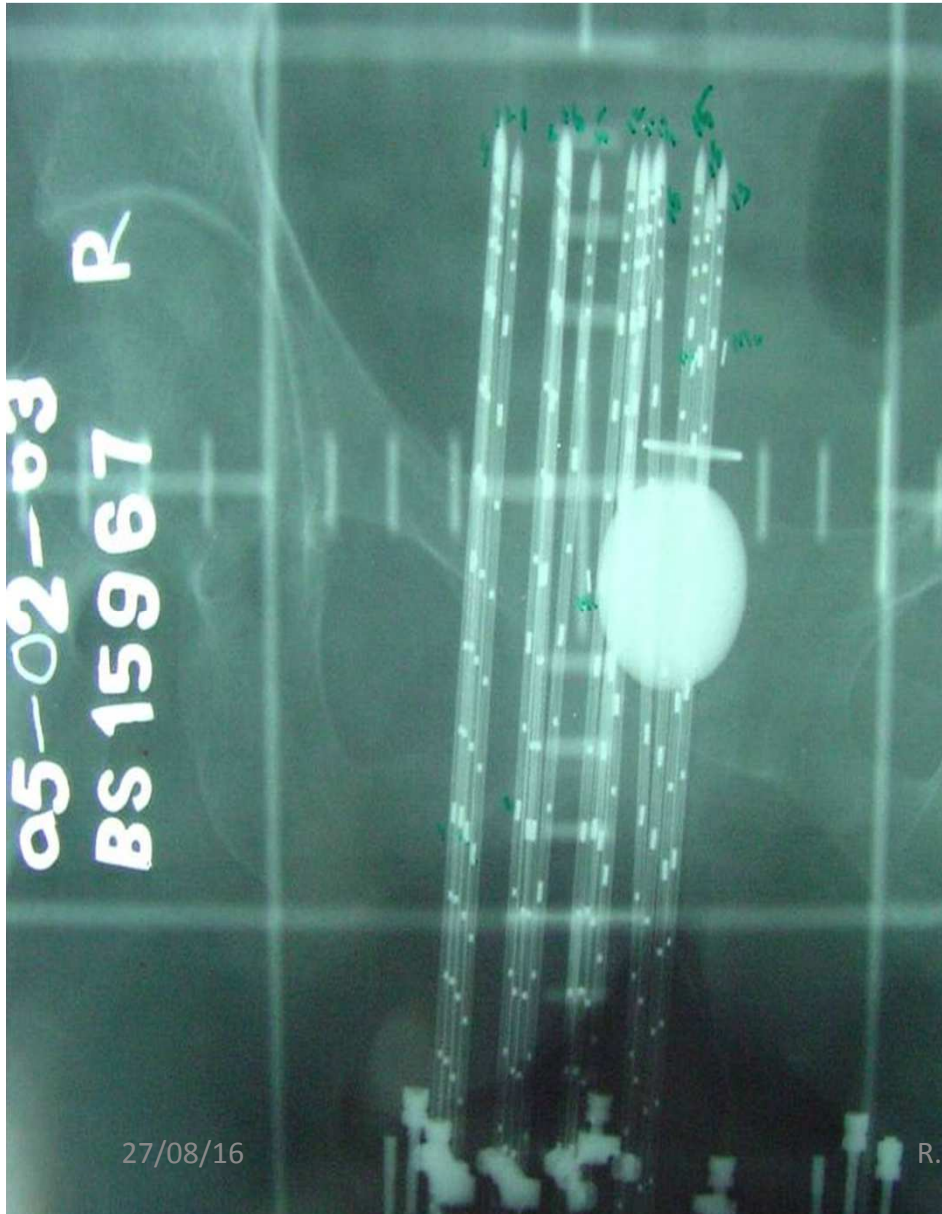


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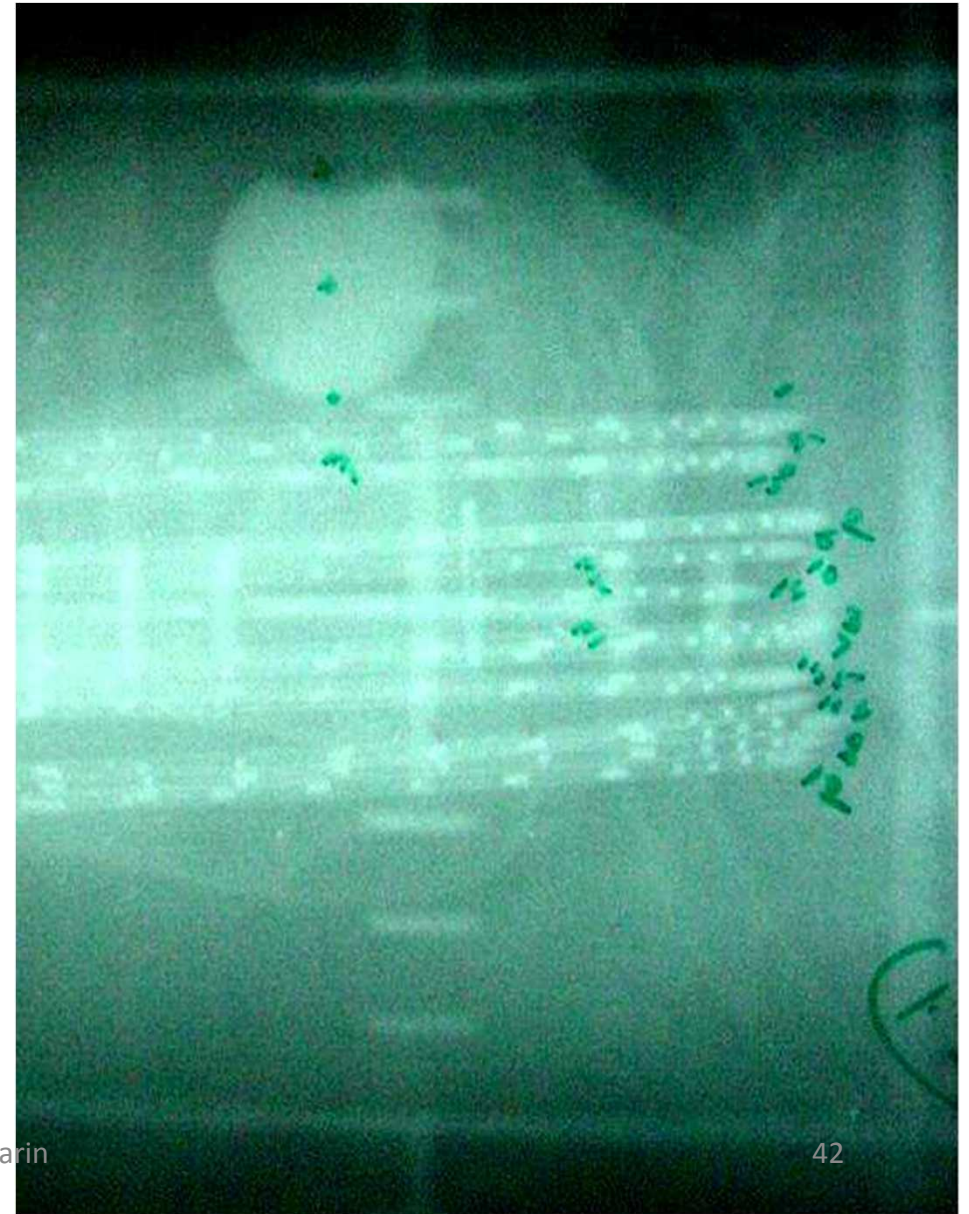
MUPIT Implant in Ca Cervix



SIMULATOR FILM OF MUPIT IMPLANT



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PERINEAL TEMPLATE FOR CA ANAL CANAL

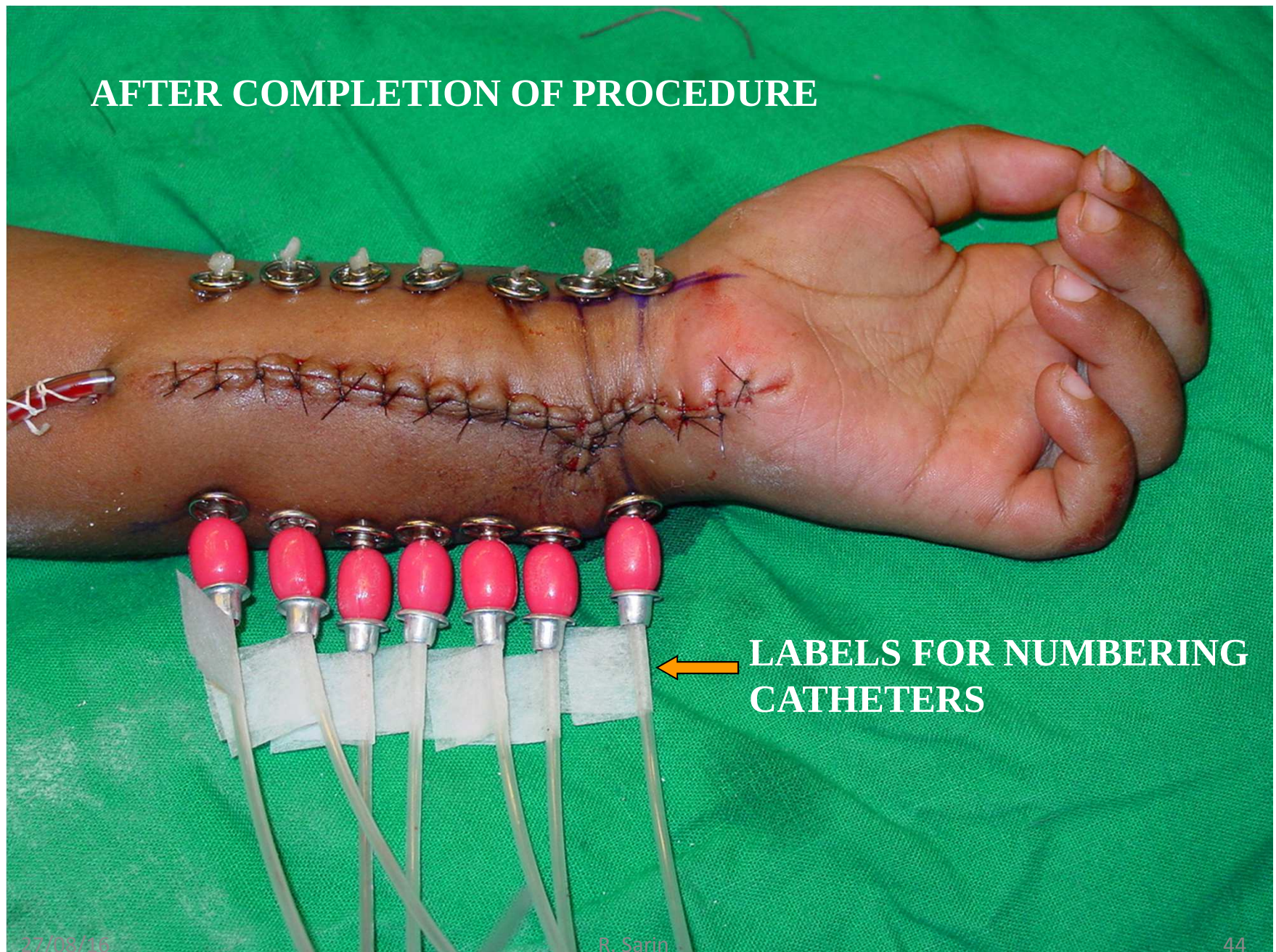


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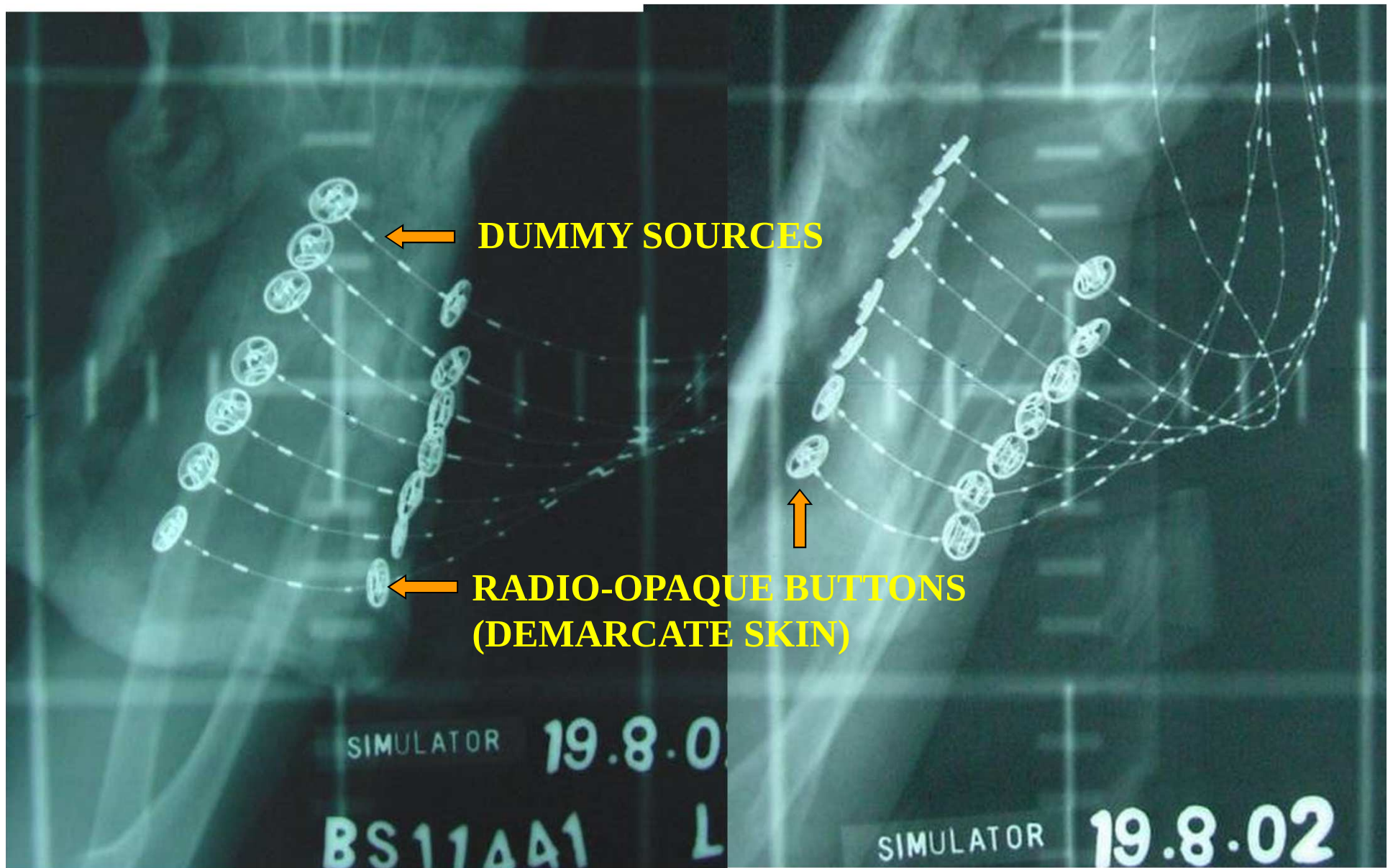
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SINGLE PLANE INTRA-OP IMPLANT for STS

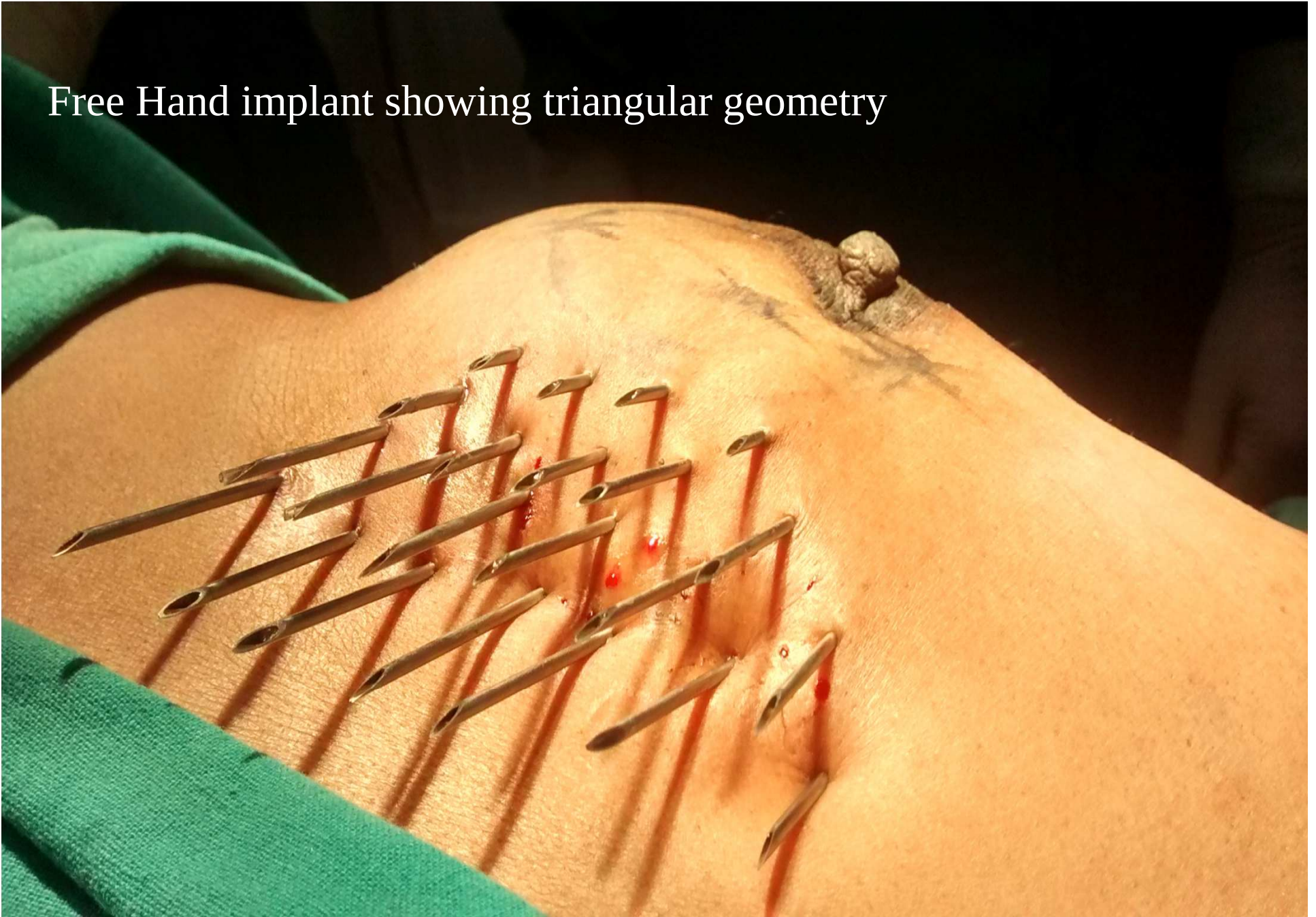
AFTER COMPLETION OF PROCEDURE

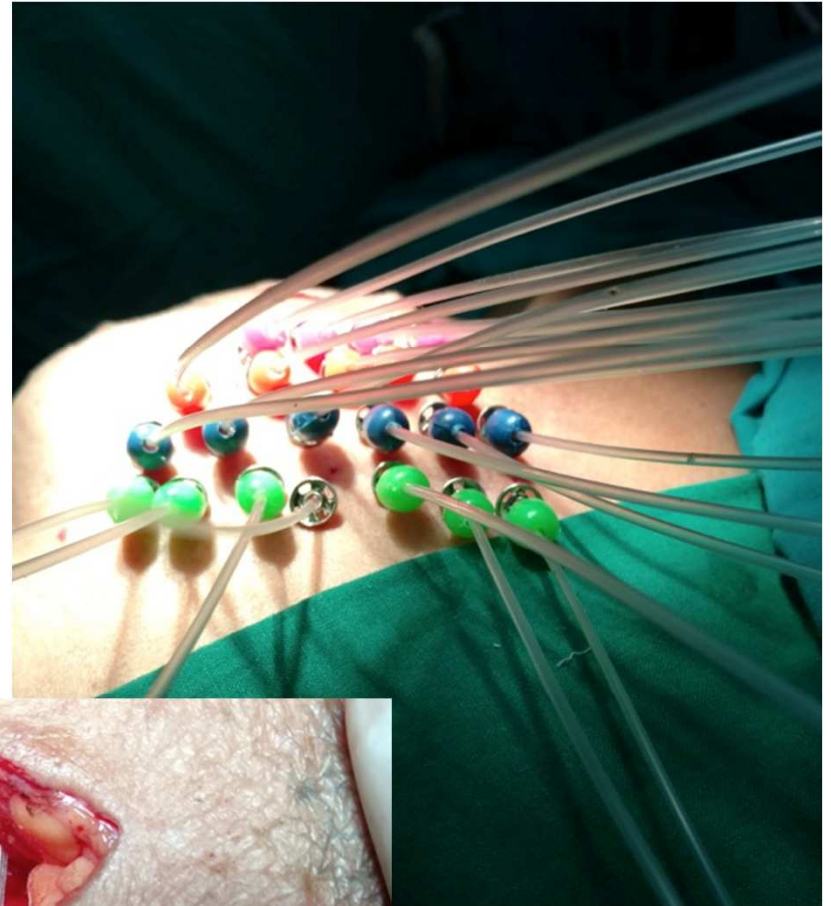


LOCALIZATION: ORTHOGONAL SIMULATION FILMS



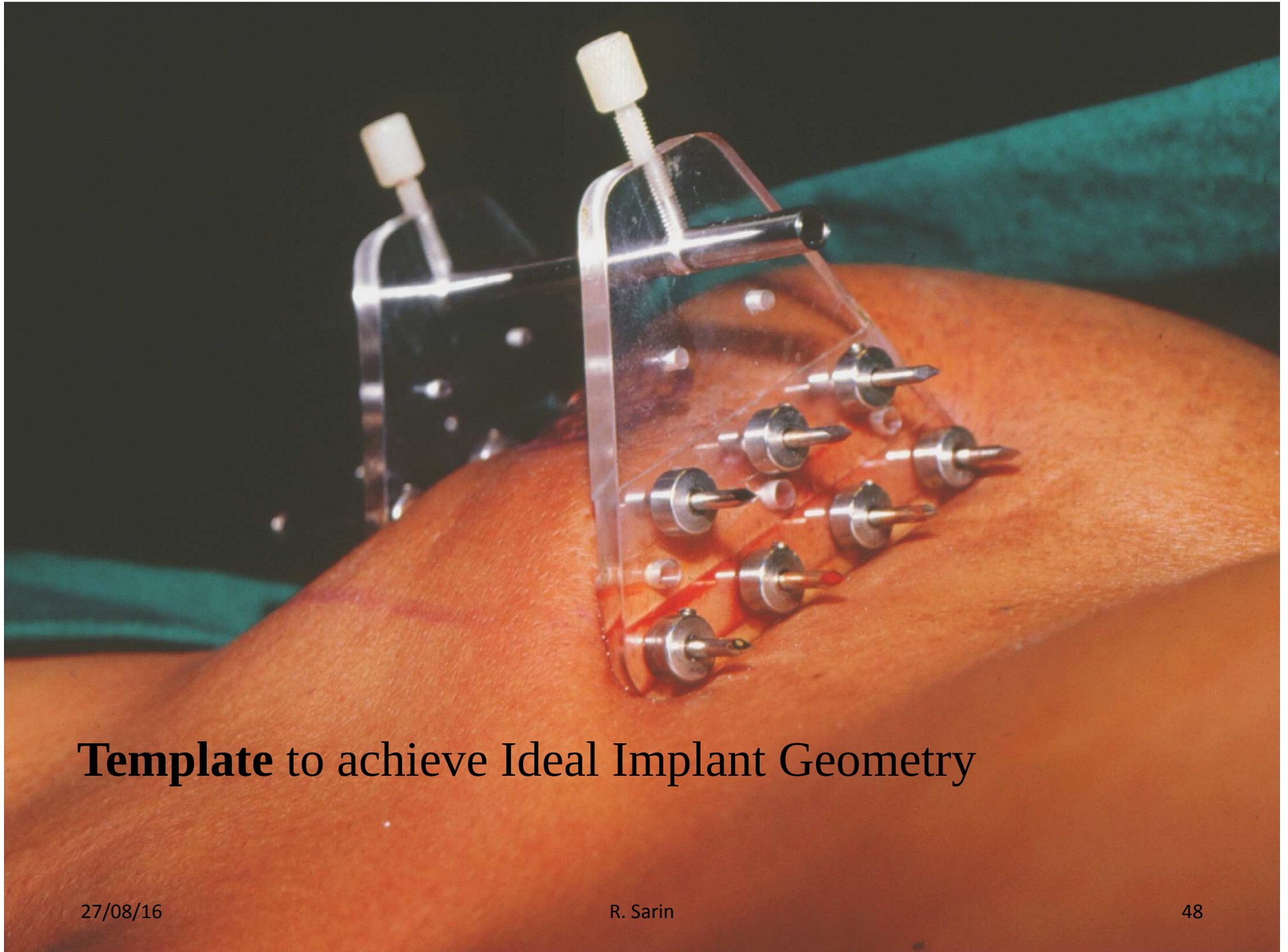
Free Hand implant showing triangular geometry



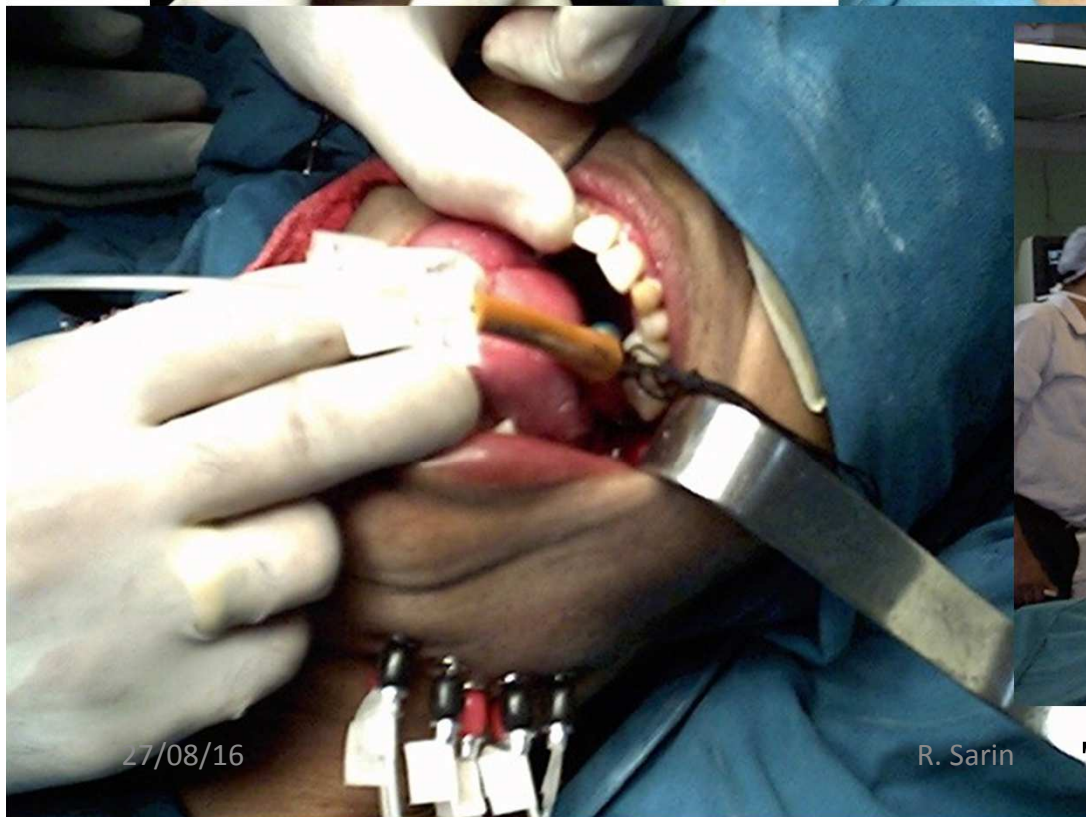
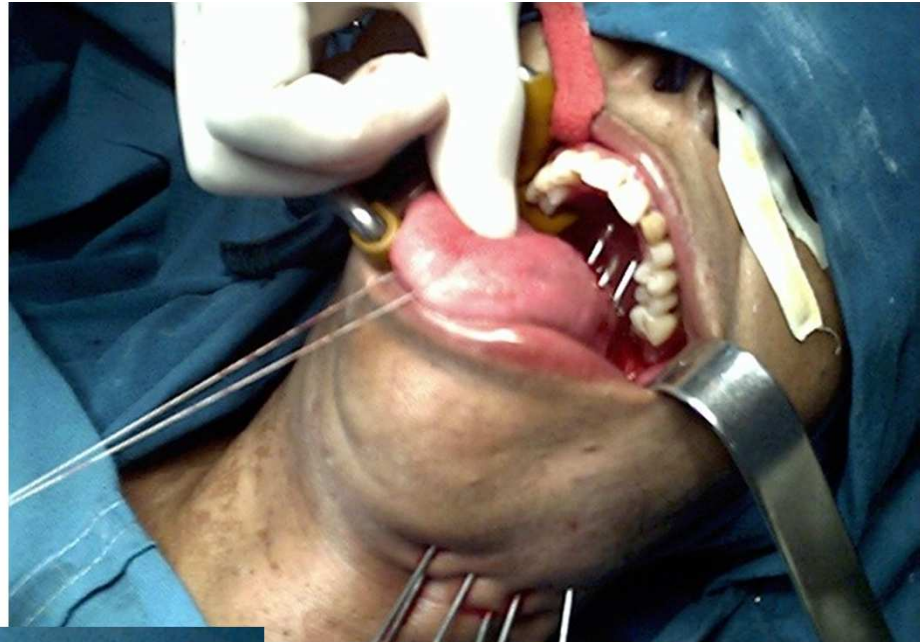
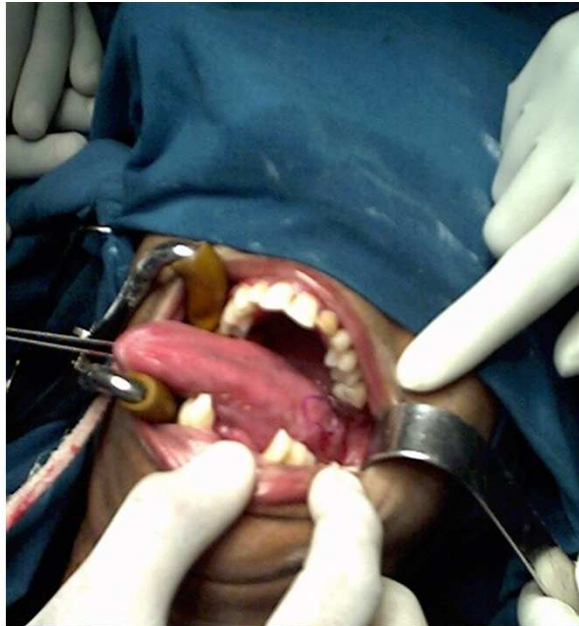


Triangular Geometry





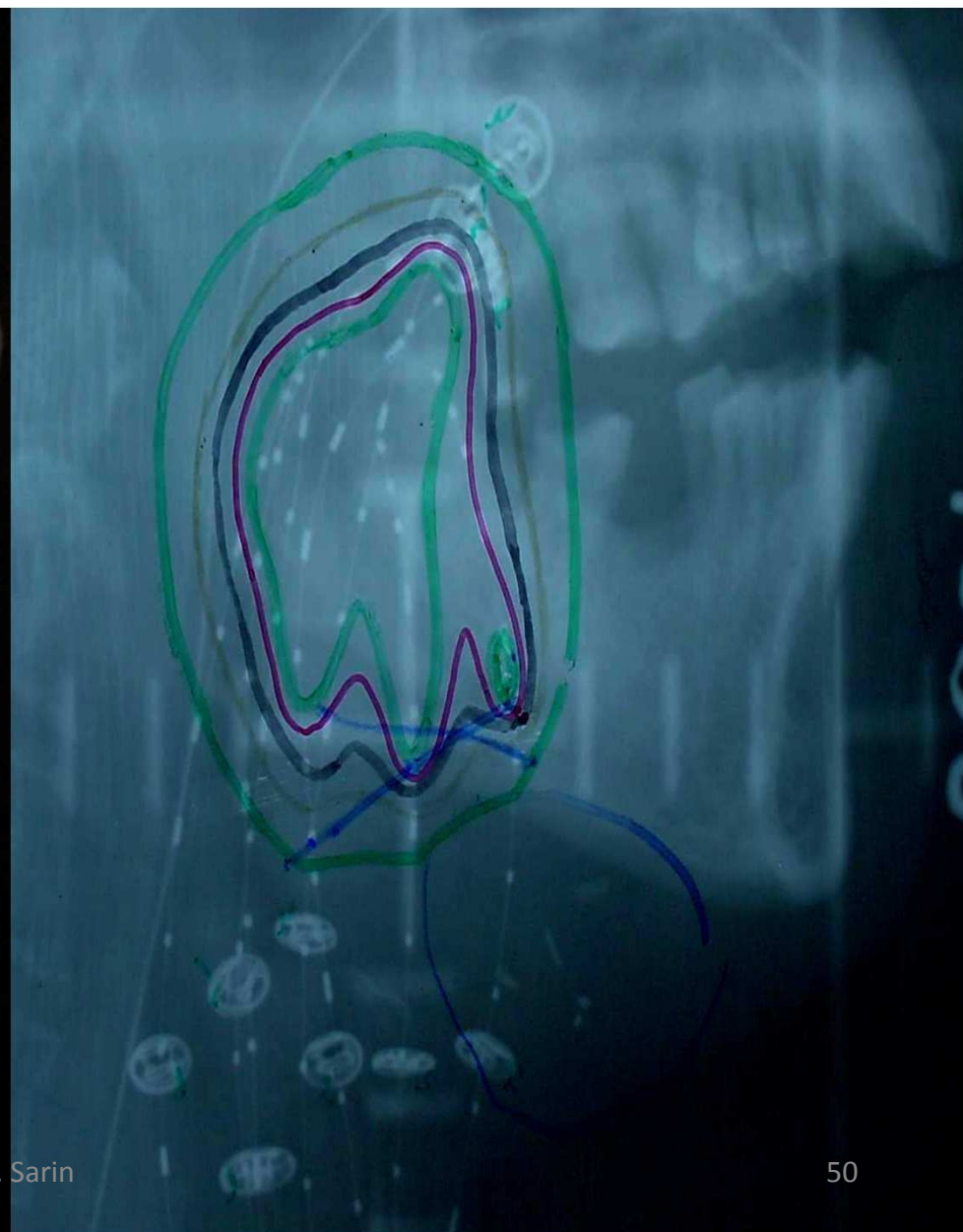
Template to achieve Ideal Implant Geometry



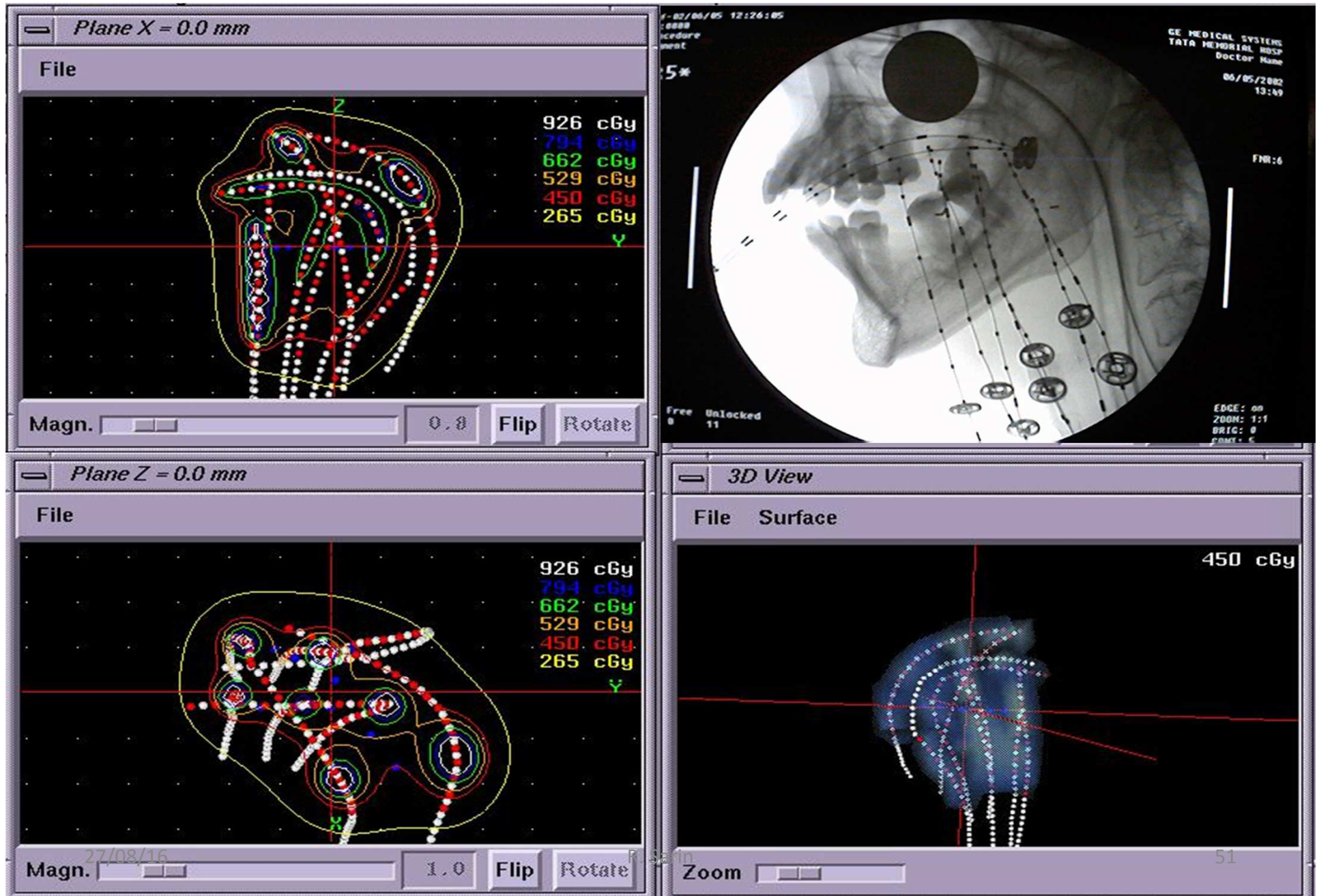
R. Sarin

Tongue implant in progress

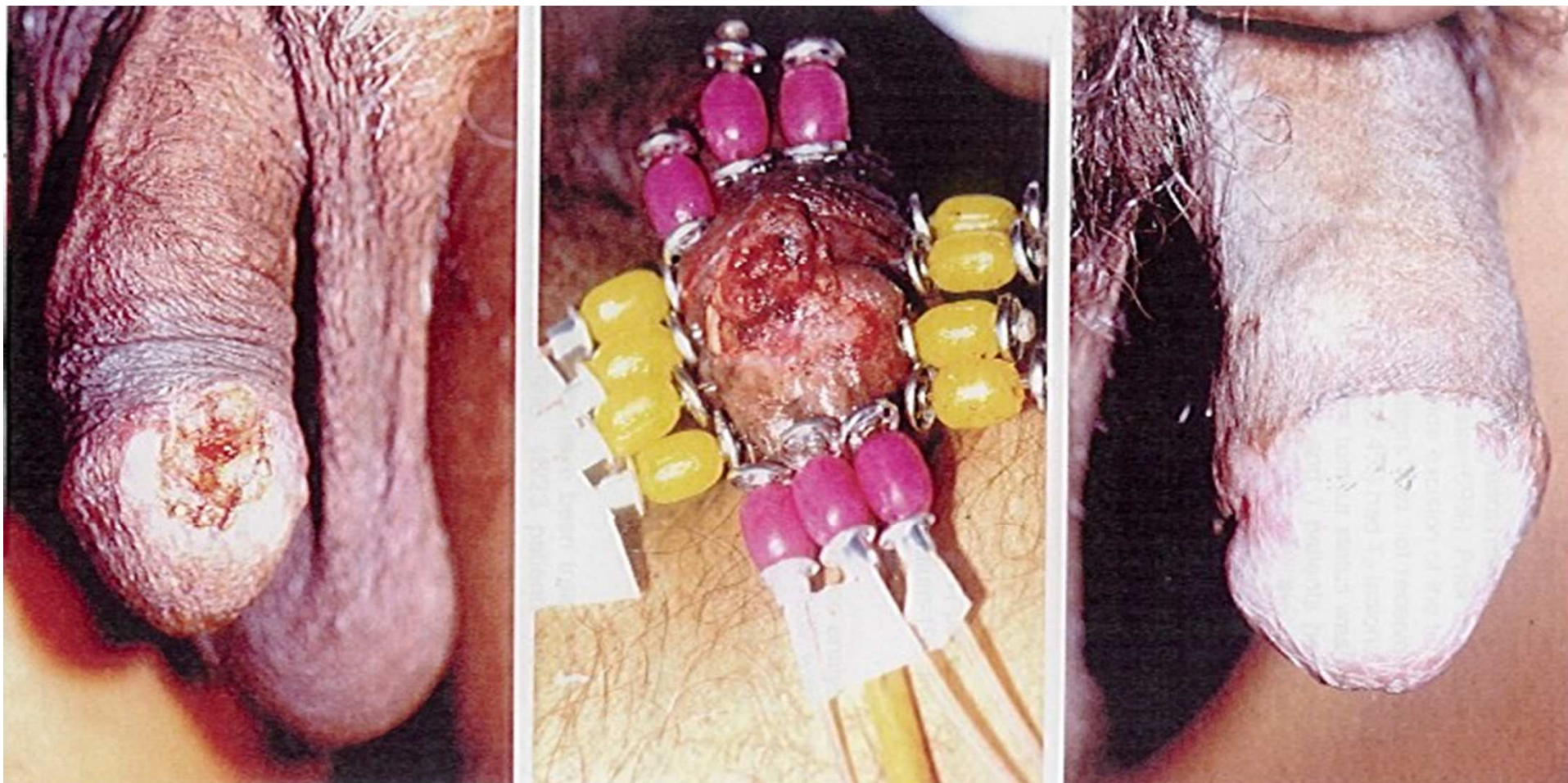
SIMULATOR FILMS & RESULTANT DOSE DISTRIBUTION



3 D Dose distribution of tongue implant



BARCHYTHERAPY FOR CA PENIS



Patient Care Before, During & After Brachytherapy

PATIENT CARE: BEFORE IMPLANT

- Apprehension & Anxiety
 - Detailed counselling about the Procedure
 - Anxiolytics and sedatives SOS
- Hygiene and infections
 - Wash & Clean; Skin Care as appropriate
 - Part Preparation
 - H&N - mouth wash / dental prophylaxis
 - Gynaec / Perineal: Vaginal Douche & enema
 - Antibiotic / Antiseptic S.O.S.
- GA fitness, control diabetes, hypertension
- Review imaging & clinical findings before brachy

PATIENT CARE: DURING PROCEDURE

- Anticipate bleeding / oedema / other technical or medical problems during procedure & manage
- Before GA confirm tumour location (breast) with patient
- Cleaning and draping
- Appropriate Positioning of patient which permits implant procedure & does not cause discomfort / pain
- Appropriate anaesthetic (usually GA)
- H&N implants: Care of airway / Cuffed endotracheal tube / Throat pack (remember to remove throat pack)
- Pain control / Epidural for perineal implants

PATIENT CARE DURING FRACTIONATED BRACHY

- Prevent and treat infections
- Meticulous hygiene
- Prophylactic antibiotics in some cases
- Sterilize theatre and instruments
- Use appropriate antiseptics for skin and mucosa
- Topical antibiotics at entry and exit site
- Change dressing only if required

PATIENT CARE: DURING PROCEDURE

Anticipate & manage bleeding

- Know the vascular anatomy & select needle path
- Avoid multiple punctures
- If any bleeding – apply pressure
- Sometimes bleeding occurs at the time of implant removal
 - Head & Neck: Pressure over artery
 - Limb Arterial bleed: Tourniquet with monitoring

Removal of Implant

- Check that all fractions / full dose given
- Proper positioning, instrument, illumination & assistance
- Analgesia, mouth wash etc.
- Remove the catheters after identifying the plane and number
- Avoid introducing infection
- Be prepared for bleeding in occasional cases

PATIENT CARE : AFTER PROCEDURE

- Analgesics, Antibiotics
- Dressing until healing of skin puncture site
- Mouth wash and Vaginal douche if appropriate
- Dental care
- Assess acute reaction and treat symptomatically
- Assess tumour response
- Appropriate follow up interval to detect recurrence or late complications timely

PATIENT CARE: DURING PROCEDURE

- Plan how you would achieve good geometry
- Check position of needles, catheters, templates regularly
- Check the position of sources
- Check for any oedema causing distortion of geometry

Sites treated with Interstitial Brachytherapy

- Lip
- Tongue
- Buccal Mucosa
- Floor of mouth
- Oropharynx
- Breast & chest wall
- Soft tissue Sarcoma
- Skin
- Prostate
- Gynaecological
- Anal canal
- Penis
- Eye Lid

Brachytherapy dosage systems

- Manchester
- Paris
- Computerized

Dose specification in intracavitary brachytherapy

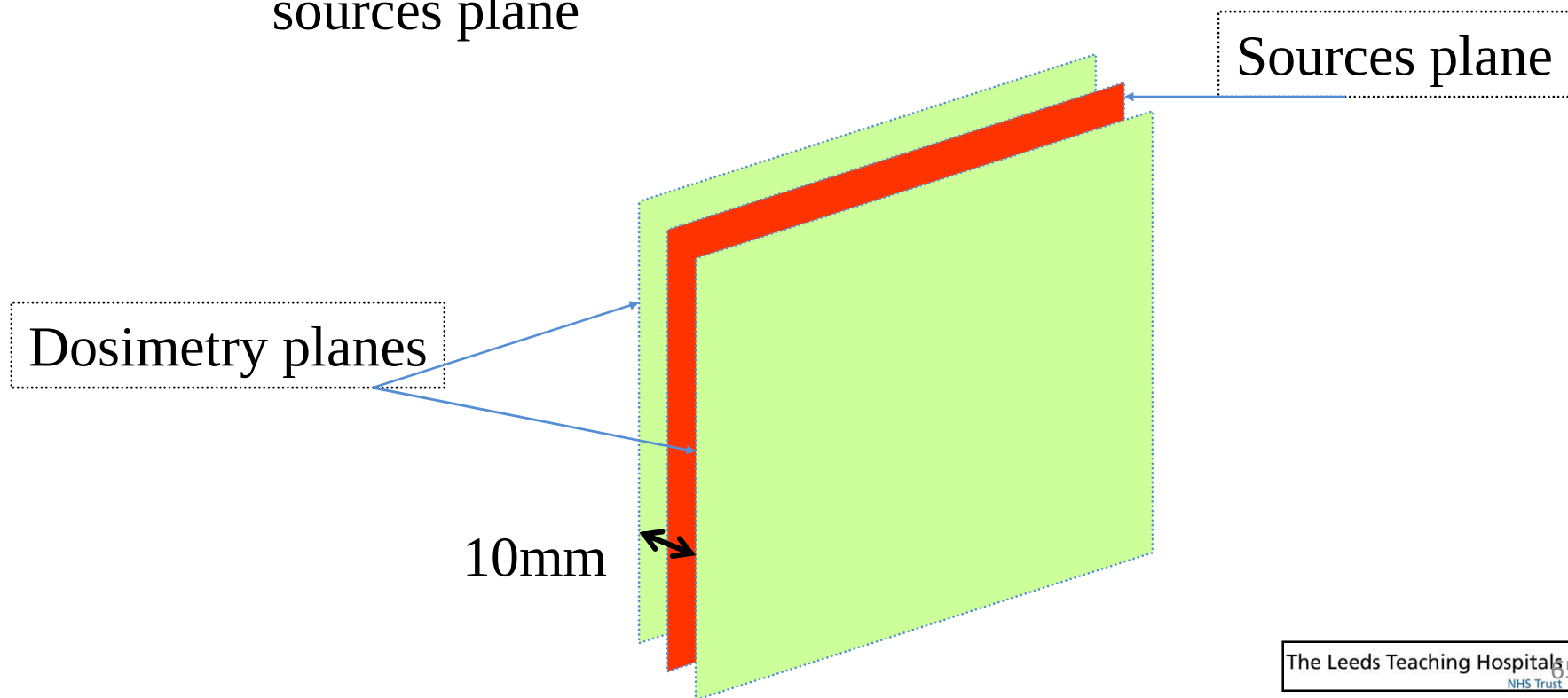
- Milligram hours
 - (Stockholm, Paris, Munich systems)
- Manchester system Point A & B
- Volumetric specification– ICRU 38

Manchester System (Paterson-Parker Rules)

- Dosage tables - to calculate amount of radium required
 - Product of the amount of radium (in mg) and the time (in hours) needed to give 1000 roentgens to the treated surface – mg-hrs per 1000R
- Distribution rules - to determine how the radioactive material is to be distributed
 - Moulds (Planar, Sandwich & Cylinder)
 - Planar implants
 - Volume implants

Planar implants

- Sources implanted in a single plane
- Dosimetry is specified on a parallel plane, 5mm from sources plane



Distribution rules for planar implants (1)

The implanted plane is divided into the “periphery” and the “area”.

Sources are arranged, as uniformly as possible, on each of these categories, the proportion depending on the area.

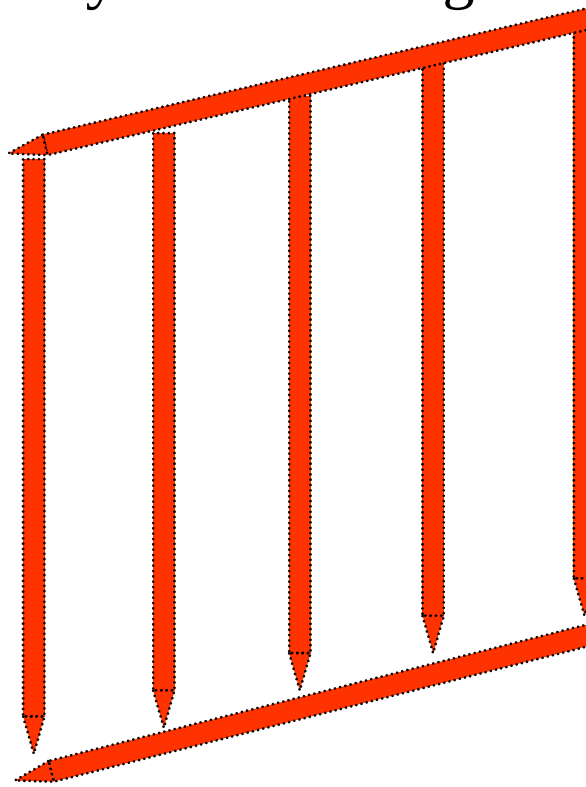
Distance between sources should not exceed 1cm

Distribution rules for planar implants (2)

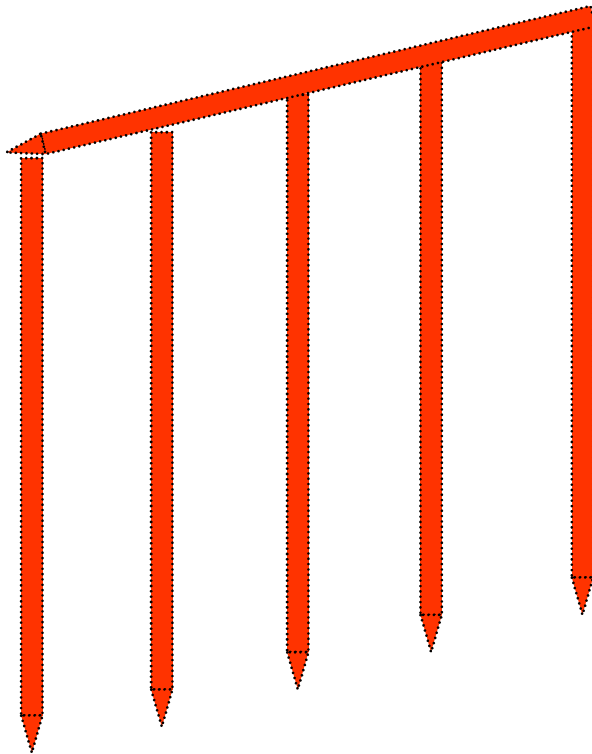
Area of implant	Peripheral Fraction	Central (Area) Fraction
<25 cm ²	2/3 rd	1/3 rd
25 to 100 cm ²	1/2	1/2
>100 cm ²	1/3 rd	2/3 rd

Distribution rules for planar implants (3)

A common arrangement is a row of parallel needles, with the ends “crossed” by needles at right angles.



Distribution rules for planar implants (4)



If ends are “uncrossed”, deduct 10% from area for “table-reading” purposes, for each uncrossed end.

What else can be done to minimize underdosage at uncrossed ends?

Distribution rules for planar implants (5)

For 2-plane implants:

- Planes should be parallel
- Area to be used for table reading is the average of the 2 areas
- Total activity divided pro-rata between the planes
- Dose mid-way between the planes is low by 10% - 30% depending on separation and area

Paterson-Parker Rules

Example (single plane implant)

Size of implant: $4\text{cm} \times 5\text{cm} = 20\text{cm}^2$

To give 6500R in about 7 days

From table, mg.hrs per 1000R = 368

$\therefore$ mg.hrs for 6500R = 2391

$\therefore$ mg required = $2391/168 = 14.2$ mg Ra

Area $< 25\text{cm}^2$, so $2/3$ (9.4mg) on periphery
and $1/3$ (4.8mg) over area.

Distribution rules for volume implants (1)

The implanted volume is divided into the “rind” and the “core”.

The activity determined from the table is divided into 8 parts, and distributed as follows:

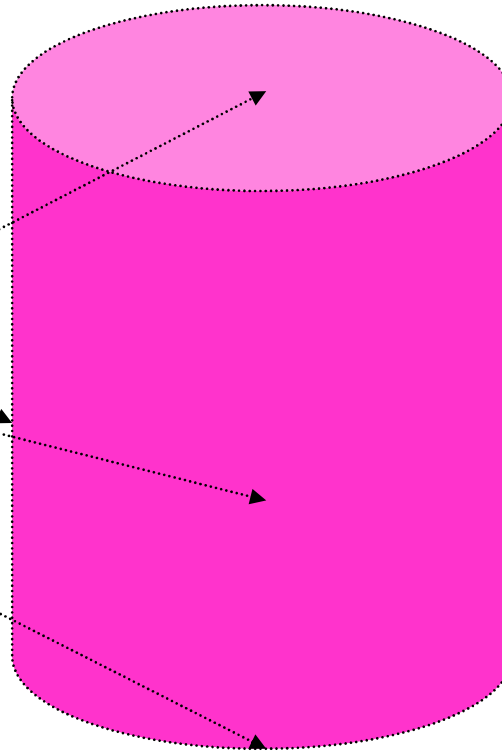
Distribution rules for volume implants (2)

Cylinder:

Belt - 4 parts

Core - 2 parts

Ends - 1 part each



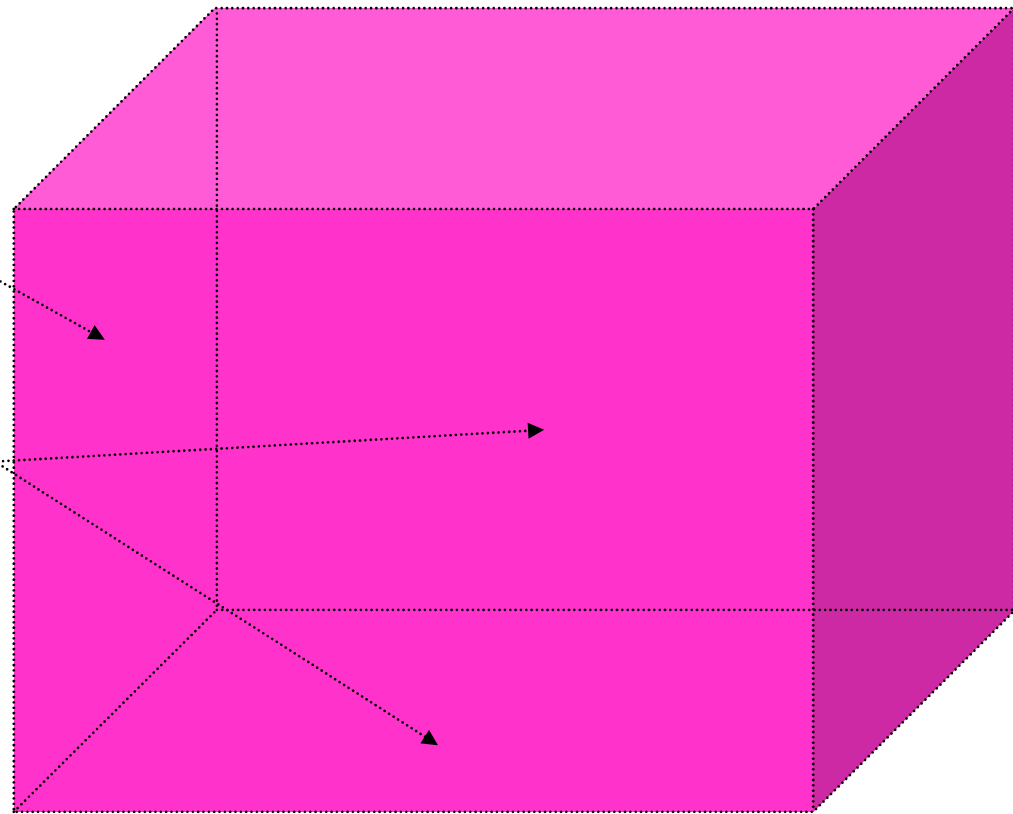
Distribution rules for volume implants (4)

Cuboid:

Each side - 1 part

Each end - 1 part

Core - 2 parts



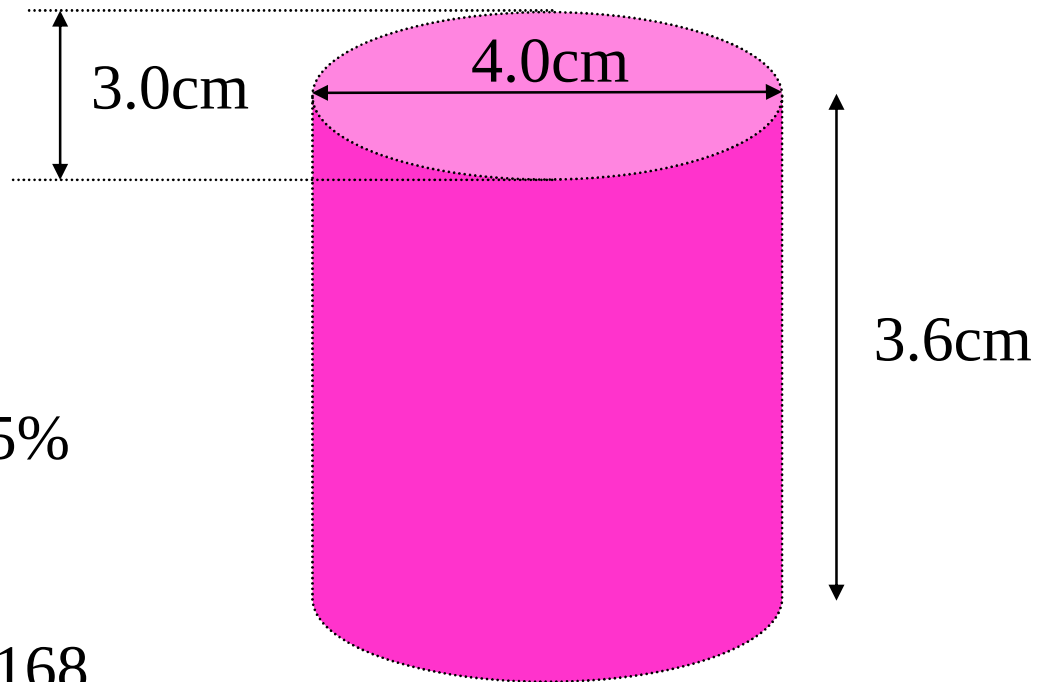
Distribution rules for volume implants (5)

- Sources should be spaced as evenly as possible on each surface, and within the volume
- Not more than 1 to 1.5cm between needles
- Correction made for “elongation” when the volume dimensions are unequal
- Correction made for uncrossed ends if necessary (-7.5% per uncrossed end)

Paterson-Parker Rules

Example (volume implant)

Elliptical cylinder,
Height 3.6cm,
Cross section 3 x 4cm.
One uncrossed end.
To give 7000R in 7 days.



Volume = 33.9cm^3 - less 7.5%
= 31.4cm^3

mg.hrs per 1000R = 340

Radium required = $340 \times 7/168$
= 14.2mg

Paris system calculation note:

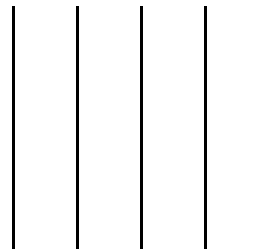
1. Dose rate data available as cross-line curves. These are available for UNIT STRENGTH OF WIRE.
so readings have to be corrected for strength used.
2. $T_{1/2} = 74$ days, so decay correction for wire strength needed. Two methods to do this:
 - a) Paris 'literature' has a correction table - add hours depending on treatment time
 - b) Calculate wire strength for (approx) middle of implant. e.g. if implant to last 6 days, calculate using wire strength on day 3

Paris system

- Use Iridium wire or hairpins
- System defines permissible geometry
- System defines method of calculating dosimetry

Implant rules

1. Sources should be straight and parallel



No crossing sources

2. Sources should be of equal length
3. Equal separation between sources. Separation may be between 5mm and 20mm.

Implant rules (cont.)

4. In cross section, sources should follow the following patterns.

Single plane



Double plane

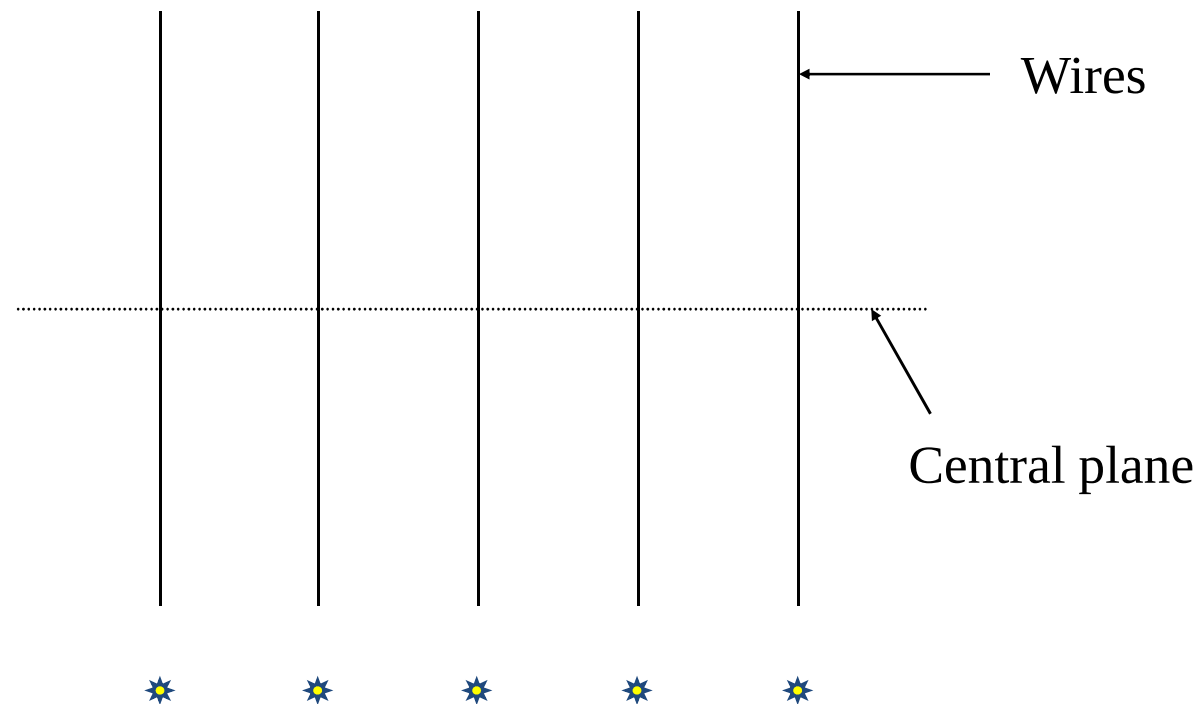


Triangles

Squares

Paris system calculation

1. Dosimetry is calculated on the central plane



2. We define a set of dose points (Basal Points) on the Central plane.

Position of Basal Points

- Basal Points between wires, at point of lowest dose

Single plane

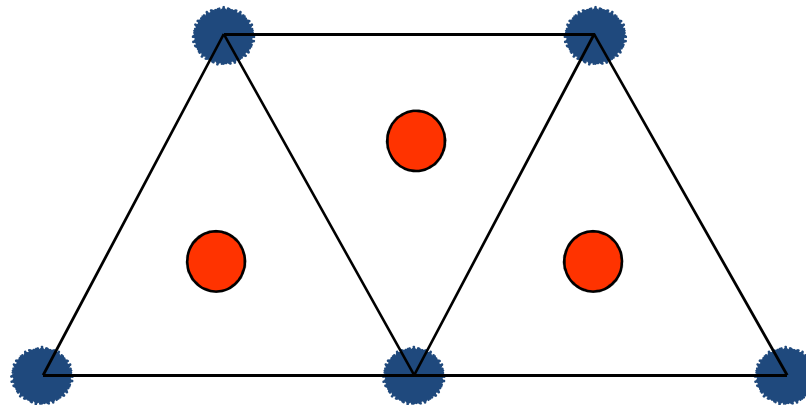


Midway between each pair of wires

Position of Basal Points

Basal Points between wires, at point of lowest dose

Two plane, triangles

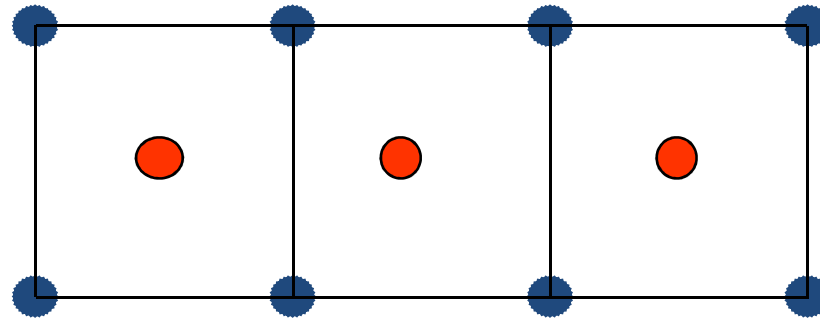


At the centre of gravity (centroid) of each triangle

Position of Basal Points

Basal Points between wires, at point of lowest dose

Two plane, squares

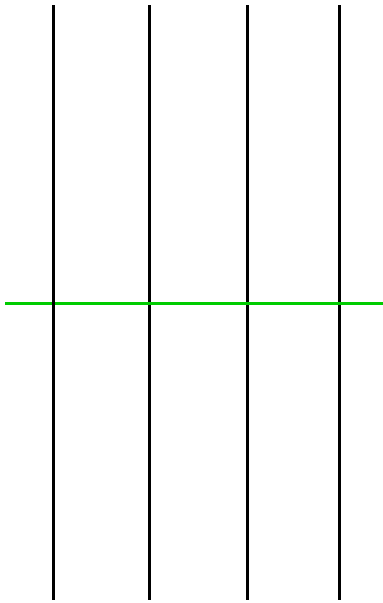


At centre of each square

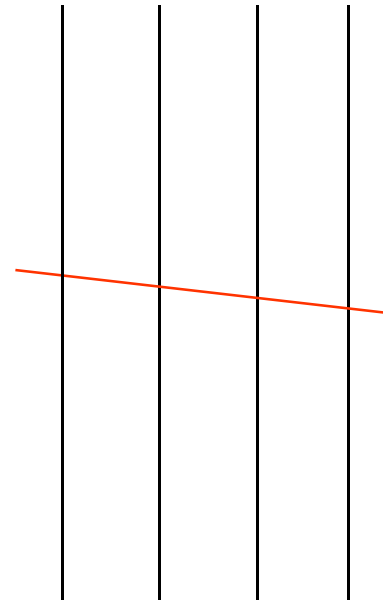
Paris system calculation (cont.)

3. Calculate the doserate at each Basal Point
4. Calculate the mean of the individual Basal Point Doserates (known as the Basal Doserate)
5. Calculate 85% of the Basal Doserate (known as the Reference Doserate)
6. Calculate the treatment time based on the Reference Doserate and the dose required

How to choose the central plane

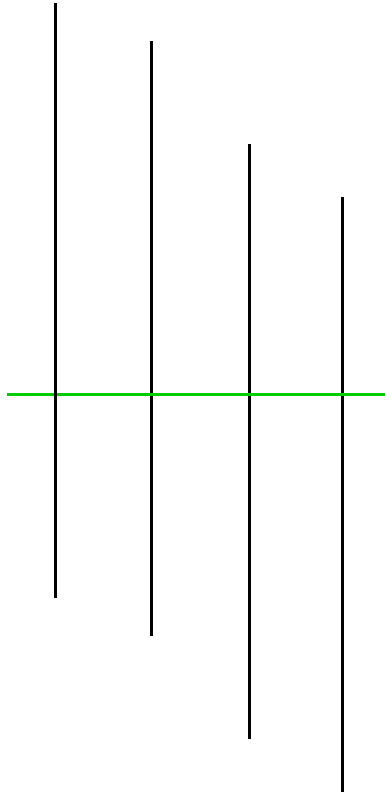


Correct

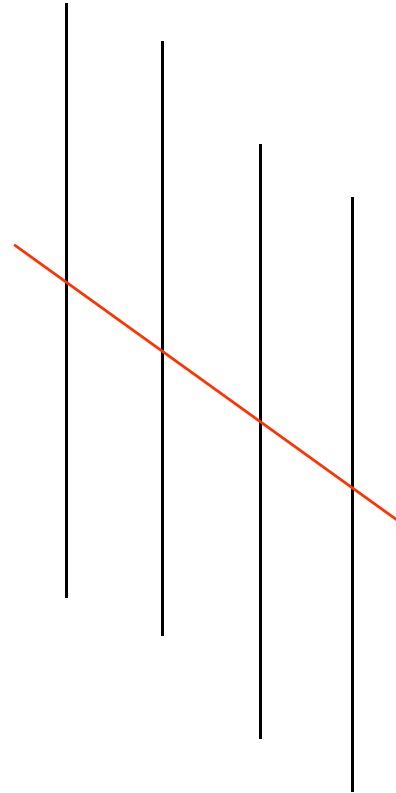


Incorrect

How to choose the central plane

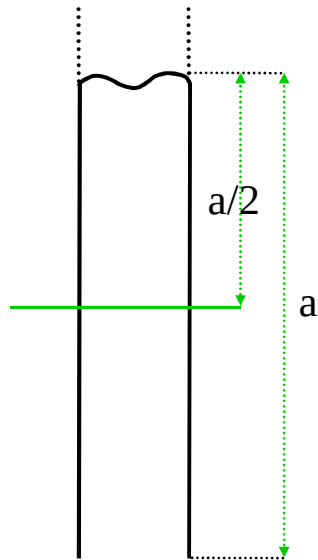


Correct

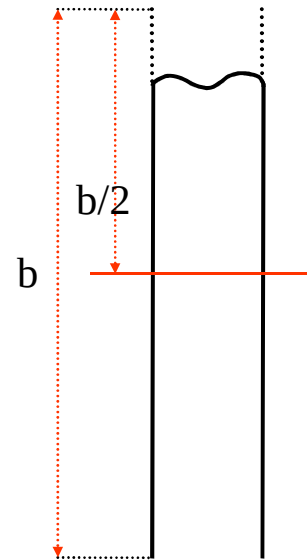


Incorrect

How to choose the central plane



Correct



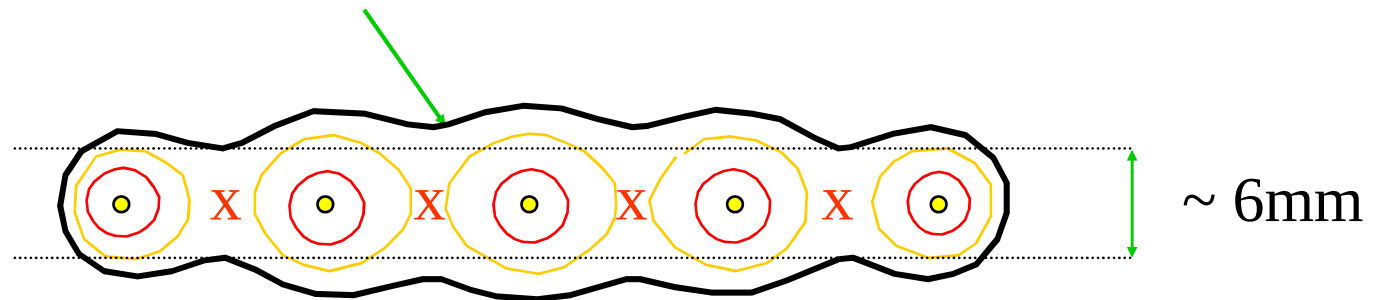
Incorrect

Thickness of treated volume

Single plane implant

0.5 x sources separation

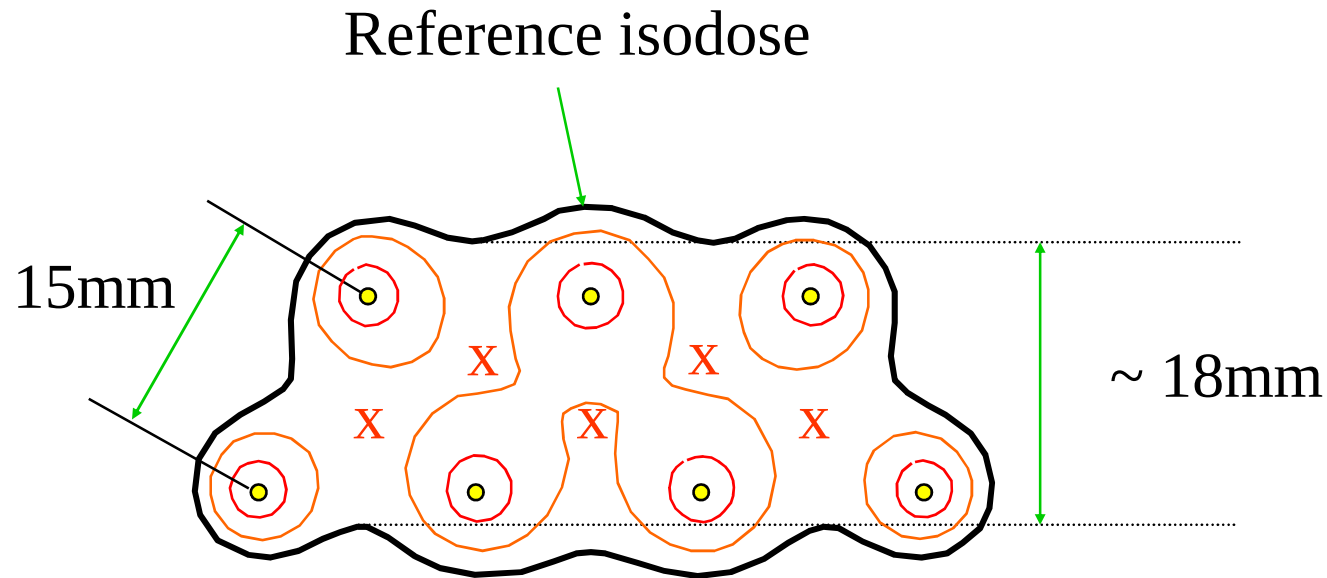
Reference isodose



12mm between wires

Thickness of treated volume

Two plane “triangular” implant [1.2 x sources separation](#)

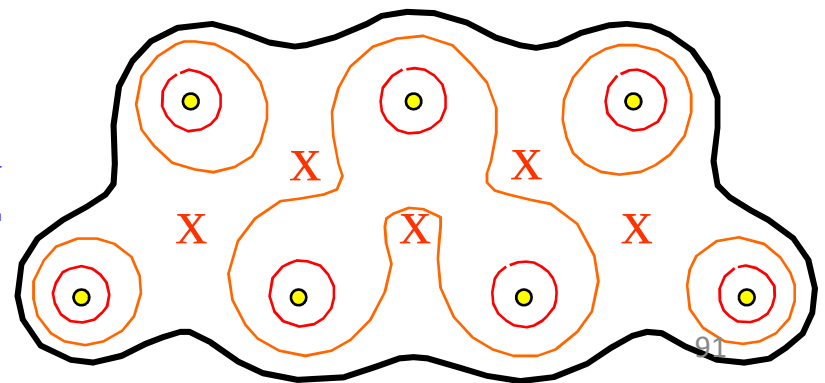


What we want to achieve (& what happens)



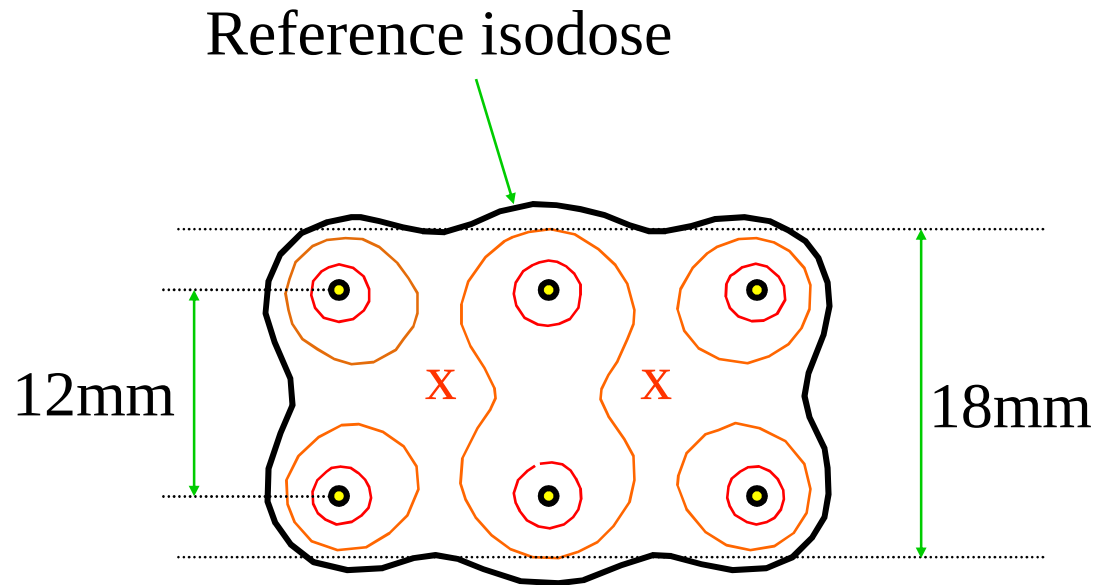
Dose Optimization by changing the Dwell position & Dwell Time

Can improve dose distribution to some extent
It can compensate for slightly sub-optimal geometry
BUT CANNOT TAKE CARE OF BAD IMPLANT



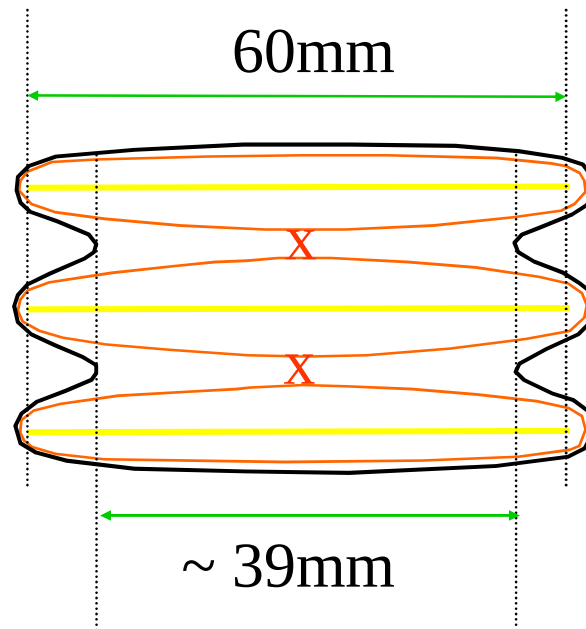
Thickness of treated volume

Two plane “squares” implant [1.5 x sources separation](#)



Length of treated volume

Single and two plane implants $0.65 \times \text{sources length}$



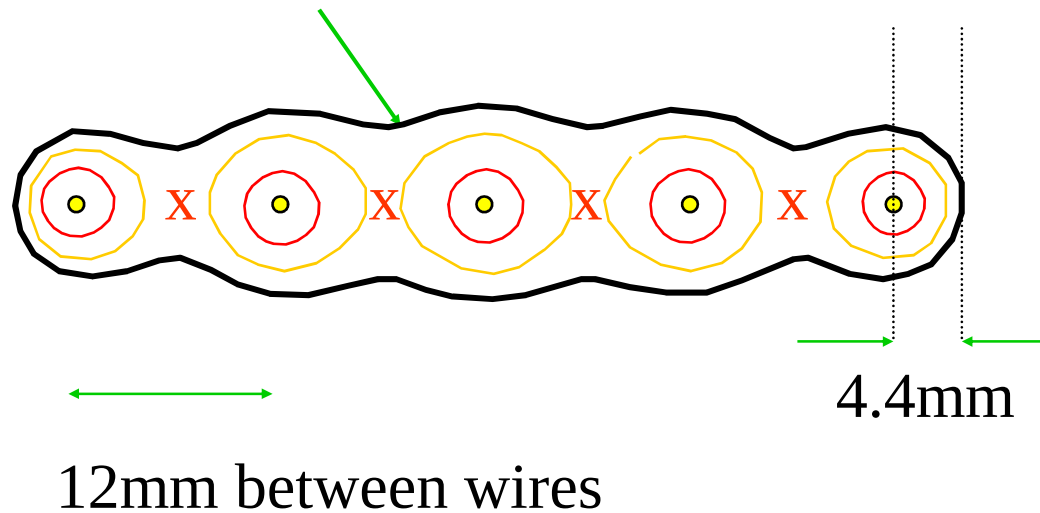
This relation is approximate, and depends a little on the wire separation, being relatively smaller for shorter wires. Another way of stating this is to say that for a particular target volume length, the sources should be about 20-30% longer, at each end, than the target volume.

Lateral margin

Single plane implant

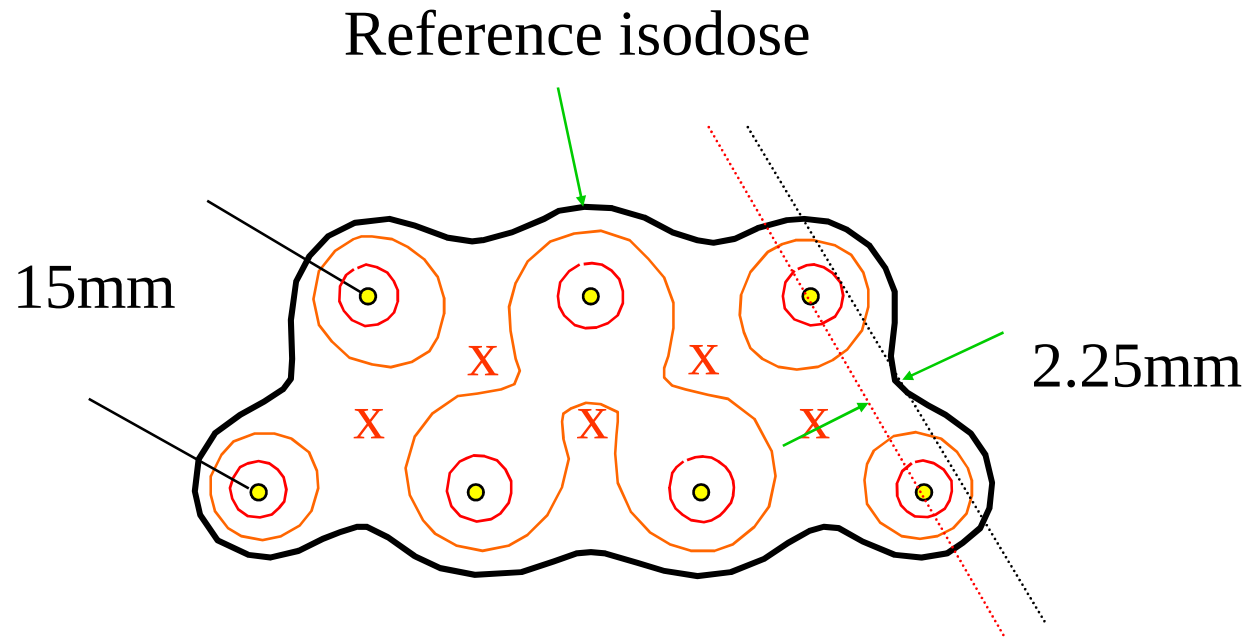
$0.37 \times$ sources separation

Reference isodose



Lateral margin

Two plane “triangular” implant [0.15 x sources separation](#)





27/08/16

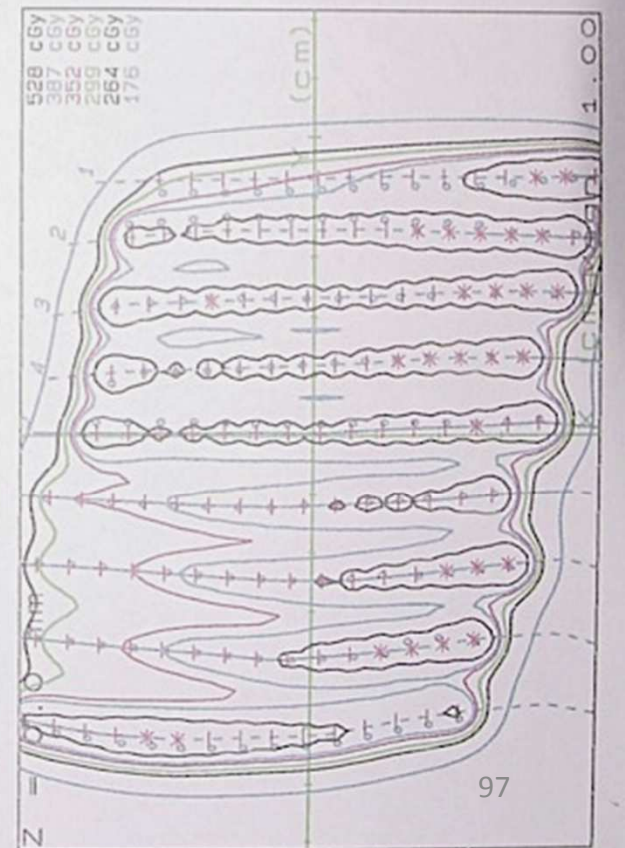
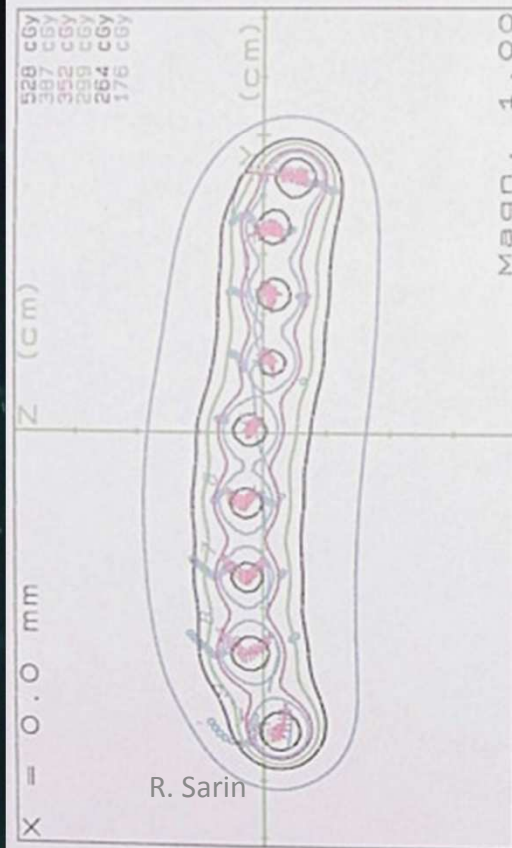
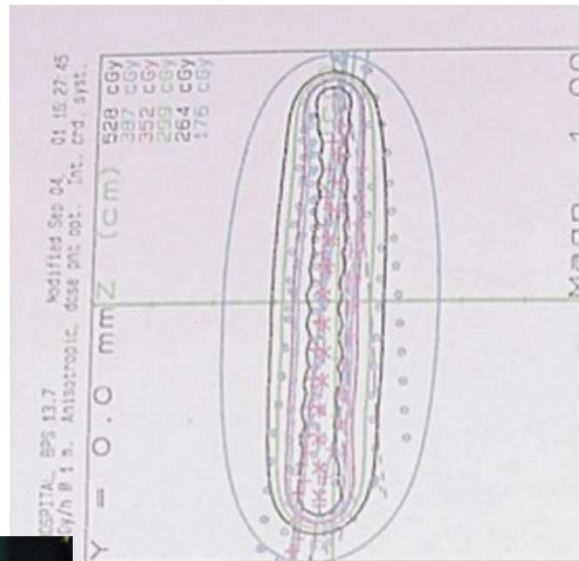
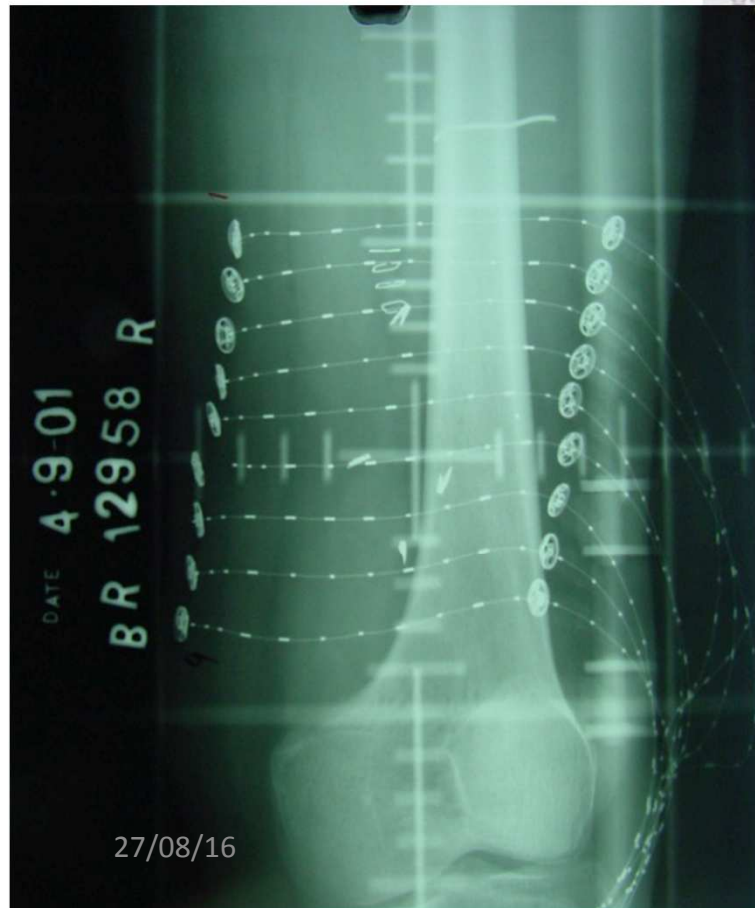
R. Sarin



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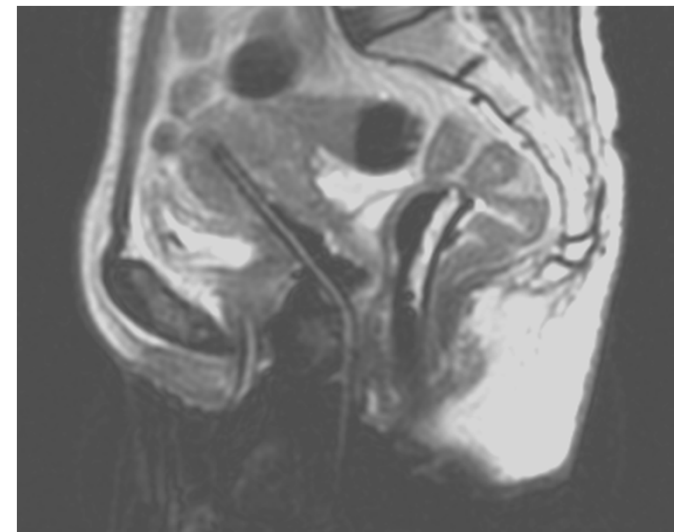
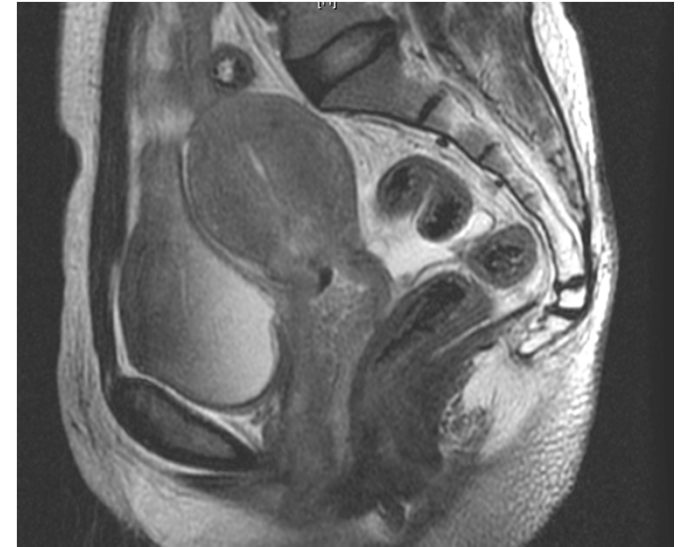
Single plane implants

- Soft tissue sarcoma
- Lip
- Skin
- Chest wall



MRI Based Brachytherapy Planning

- Good soft tissue contrast
- True multi-planar imaging
- Differentiation between cervix, uterus, tumor and para-uterine tissue
- Rectum, bladder, sigmoid and small intestine visualized
- Limitations:
 - Expensive
 - Special applicator
 - logistics



MR Based ICA in use last 6 - 9 years now

Re-emergence of ^{60}Co as brachytherapy source

- No need for frequent replacements
- Cost effective
- Miniaturised (same size of conventional ^{192}Ir source)
- High activity
- Low operating cost.



Front of the Marie Curie Gold Medal award

World Congress of Brachytherapy

Marie Curie Gold medal

awarded to those with seminal contribution to the development of Brachytherapy or **Curietherapy**

1996: Basil Hilaris, USA

2000: Henry Pierquin, France

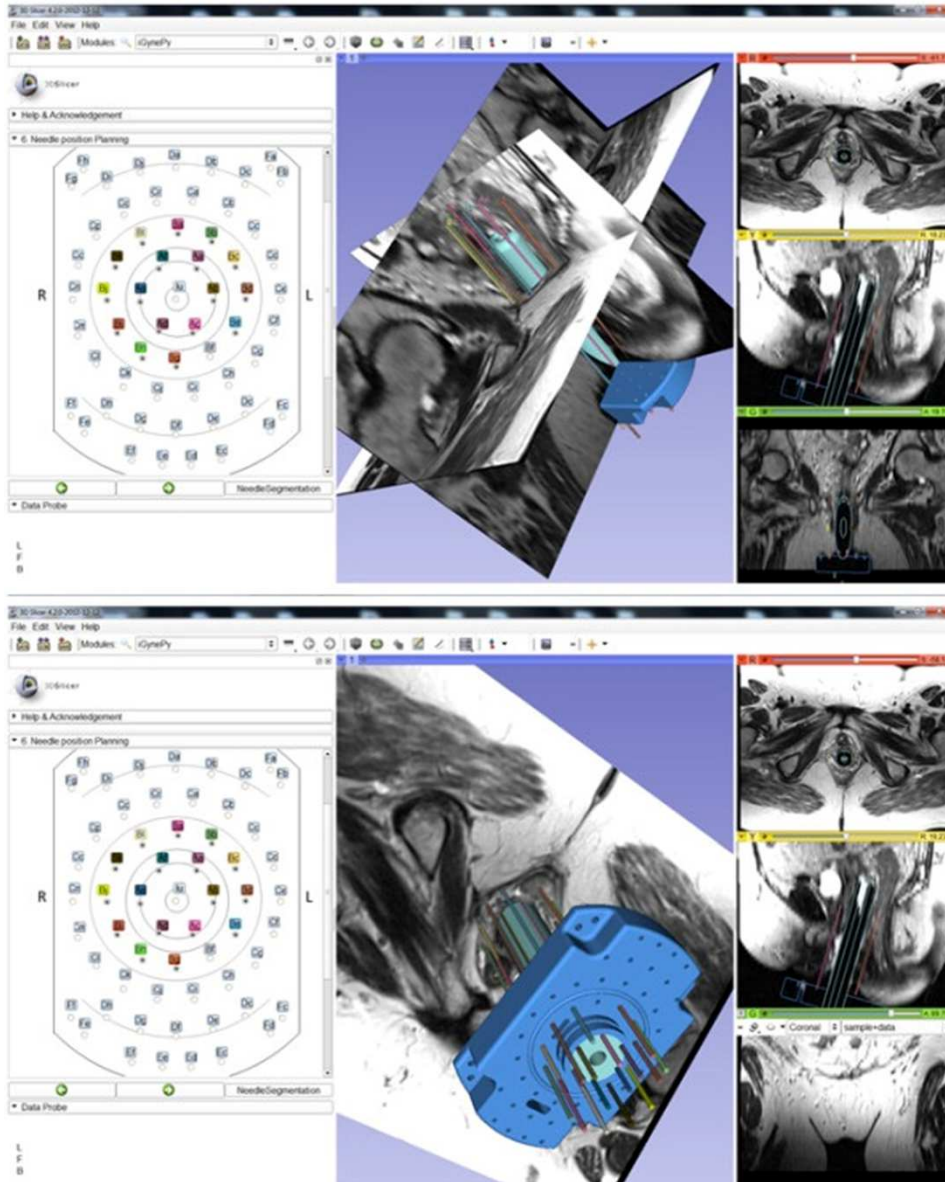
2004: Louis Delclos, USA

2008: Monique Pernot, France

Future Directions

- Better radio-isotopes
- Refinement of Applicators & techniques
- Faster & more accurate computerized planning and dose optimization
- Radiobiological modeling for tumor and Organs at Risk
- Image guidance, CT / MRI / USG

Advanced Image Guided Brachytherapy



Jan Egger, Springer Plus, 2013

27/08/16

R. Sarin

Linking a diagnostic imaging set in real-time to a 3D - CAD model of a medical device

Ability to perform patient-specific pre-implant evaluation by assessing the placement of interstitial needles prior to an intervention via virtual template matching with a diagnostic scan

Precise identification of catheter location in the 3D imaging model with real-time imaging feedback