Brachytherapy versus Teletherapy

An Introduction to Pre-Final MBBS

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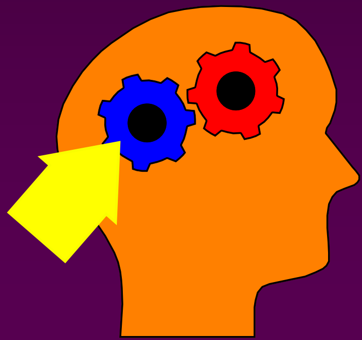
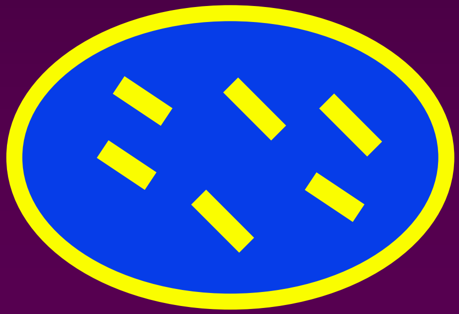
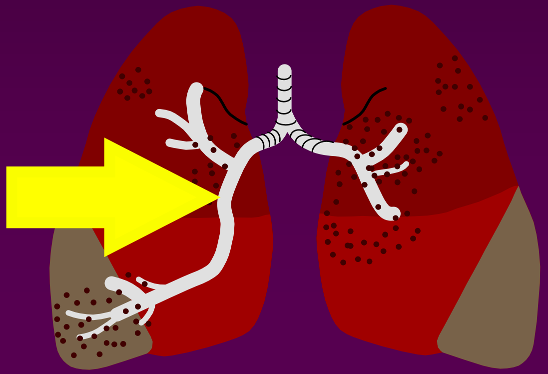
WHAT IS BRACHYTHERAPY

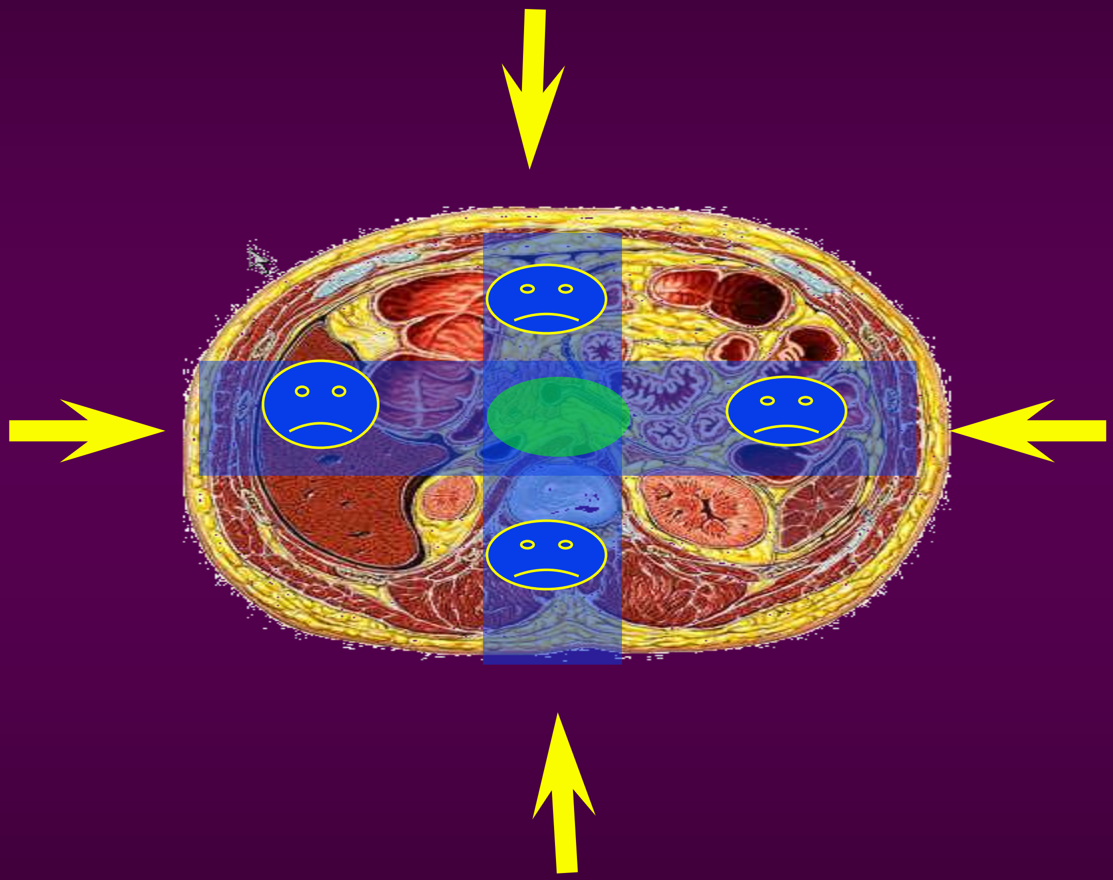


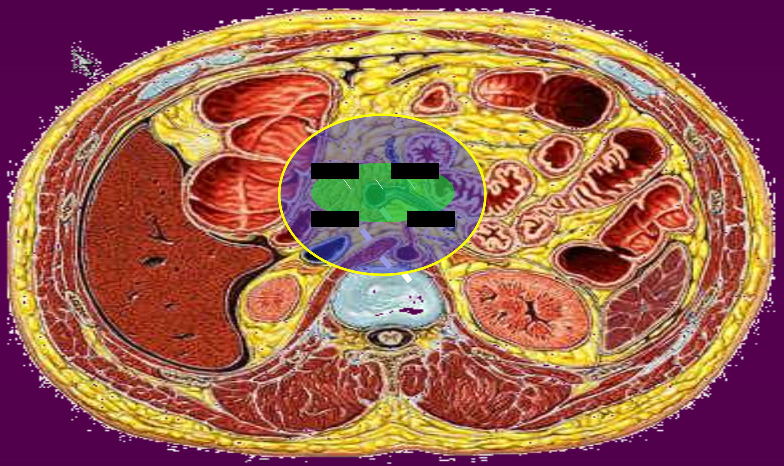




- Brachios (Greek) - short distance
- Implantation of encapsulated radioisotopes inside/close to tumor

EBRT vs brachytherapy



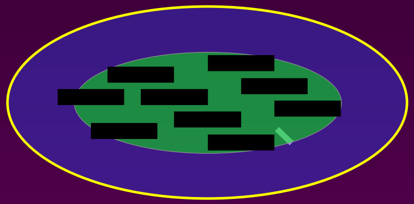


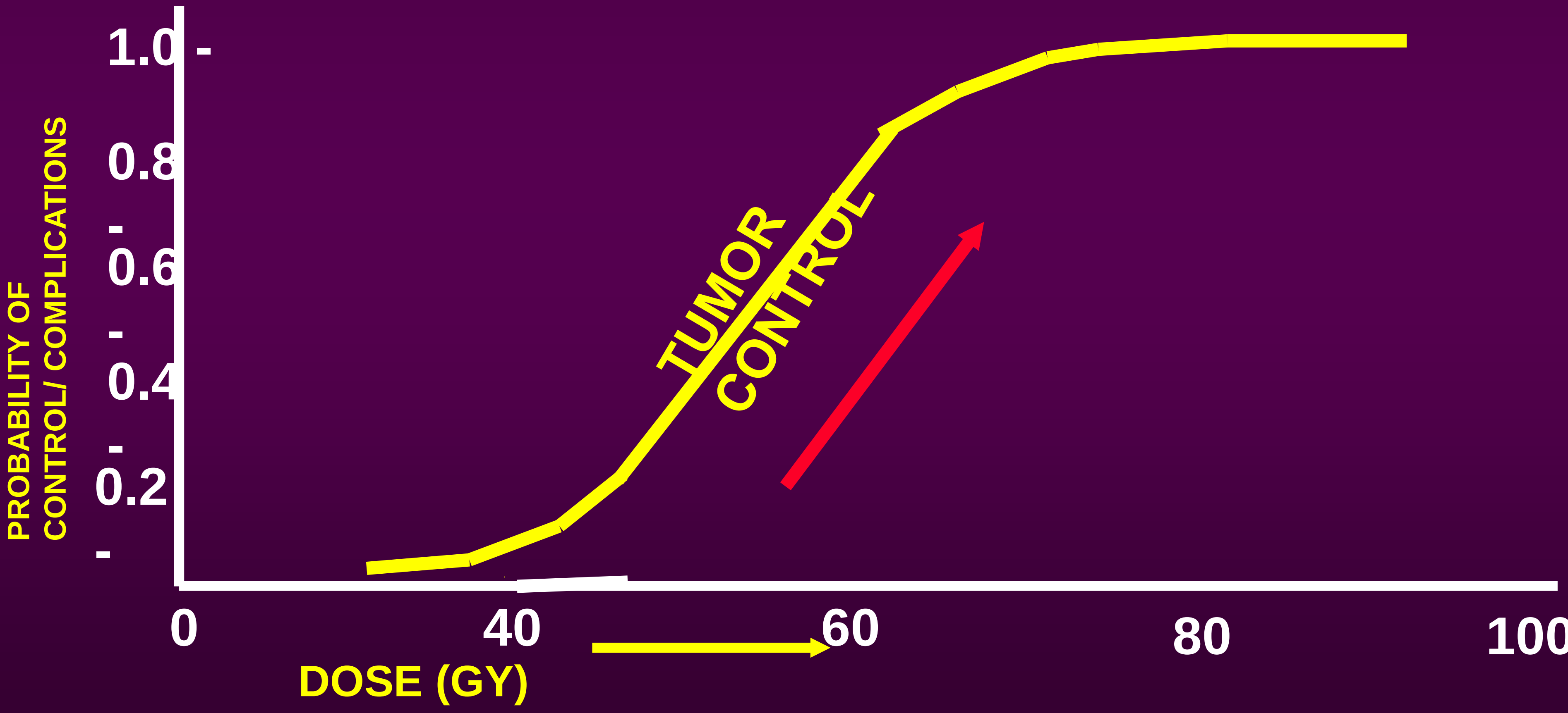
EBRT

Brachytherapy

Advantages of Brachytherapy

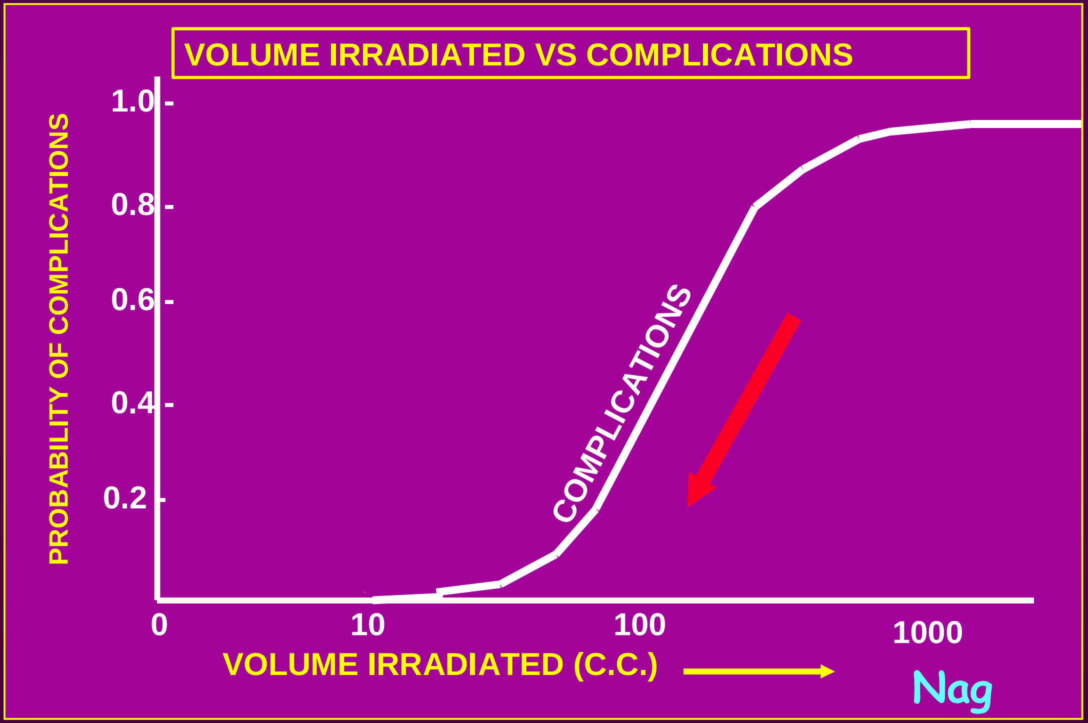
- High tumor dose
- Better tumor control





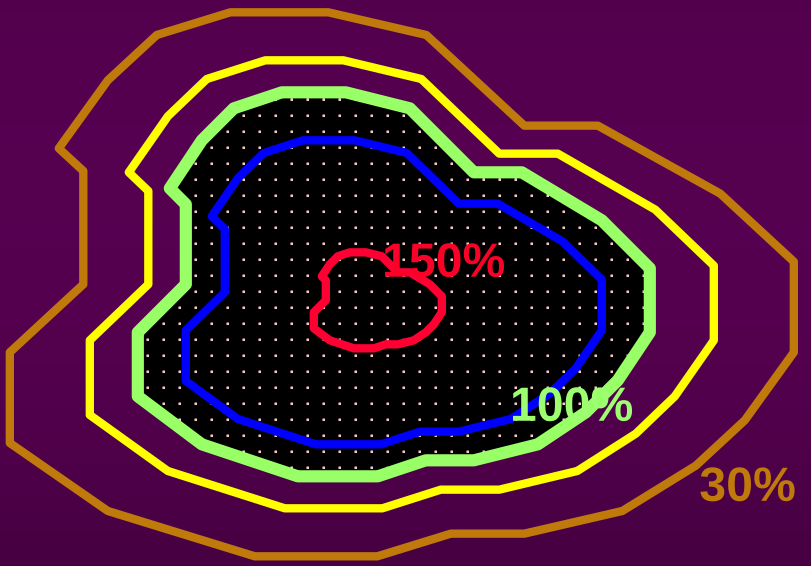
Advantages of Brachytherapy

- Rapid dose fall-off (inverse square law)
- Smaller volumes irradiated
- Lower morbidity risks



Advantages of Brachytherapy

- Conforms to irregular tumor volumes
- Avoids geographical miss - moves with tumor
- Peripheral dose is minimum dose.
- Center of tumor (hypoxic/radioresistant) receives up to 50% higher dose



Disadvantages of Brachytherapy

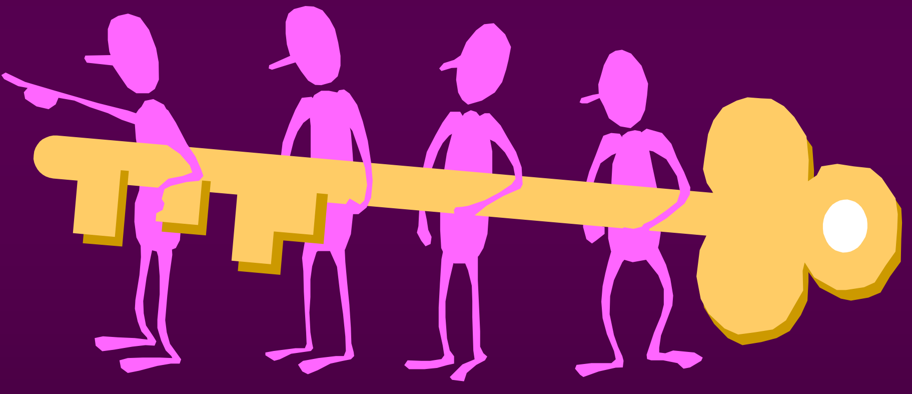
- Radiation exposure hazards -
  - minimized by low energy isotopes and remote afterloading
- Hospitalization required-
  - eliminated by HDR
- Small volumes irradiated
  - Risks marginal miss, does not treat lymph nodes or large tumors
  - Can add EBRT
- Difficult techniques/ lack of expertise
  - Major impediment
  - Books, courses, fellowships, society

Type of Brachytherapy: By Emission

- Gamma emitters (most common)
  - high energy - better penetration; requires protection
  - Low energy - less penetration; less protection
- Beta emitters - short penetration, minimal protection reqd, unless spillage. Usually used as unsealed sources for systemic use. Sealed use is possible.
- Neutron emitters - californium-252
  - more effective against hypoxic cells
  - greater hazards

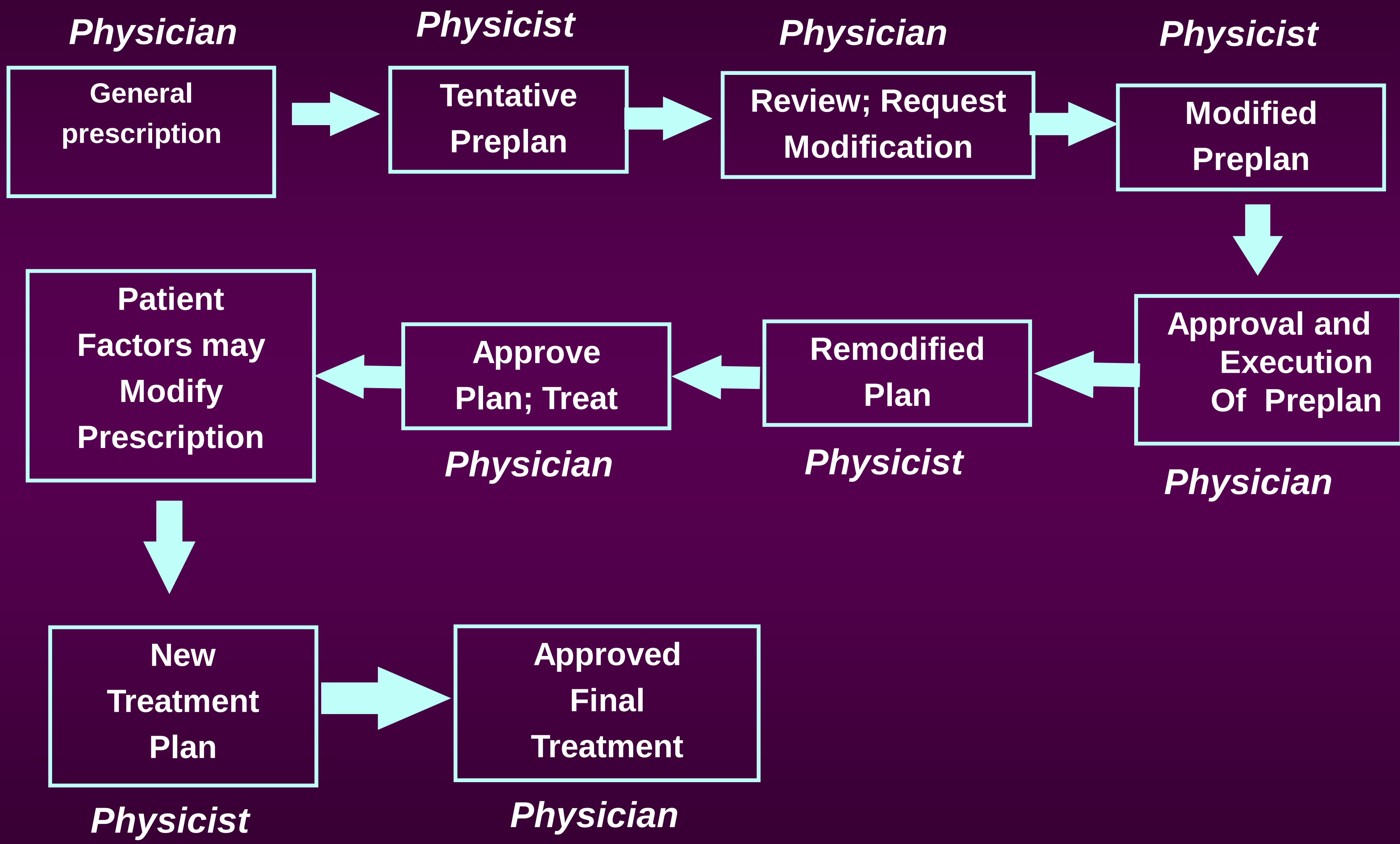
TREATMENT PLANNING

- Most important component of brachytherapy
- Highly interactive process between physician and physicist



Team effort is KEY

Treatment Planning Process



Brachytherapy Treatment Planning

- Clinical Treatment Planning
- Technical Planning
- Localization and dose calculation

- Varies with:
  - Site
  - Location
  - Experience
  - Tumor type

Clinical Treatment Planning

- Clinical evaluation of patient
  - to treat or not to treat (metastasis, co-morbid conditions, life expectancy)
  - definitive vs palliative
  - brachytherapy alone or
  - combine with surgery, chemotherapy and/or EBRT

Indications for Brachytherapy

Brachytherapy Alone:

- Small, localized tumors (e.g., prostate)
- Palliation - to reduce overall treatment times
- Tumors recurrent after EBRT

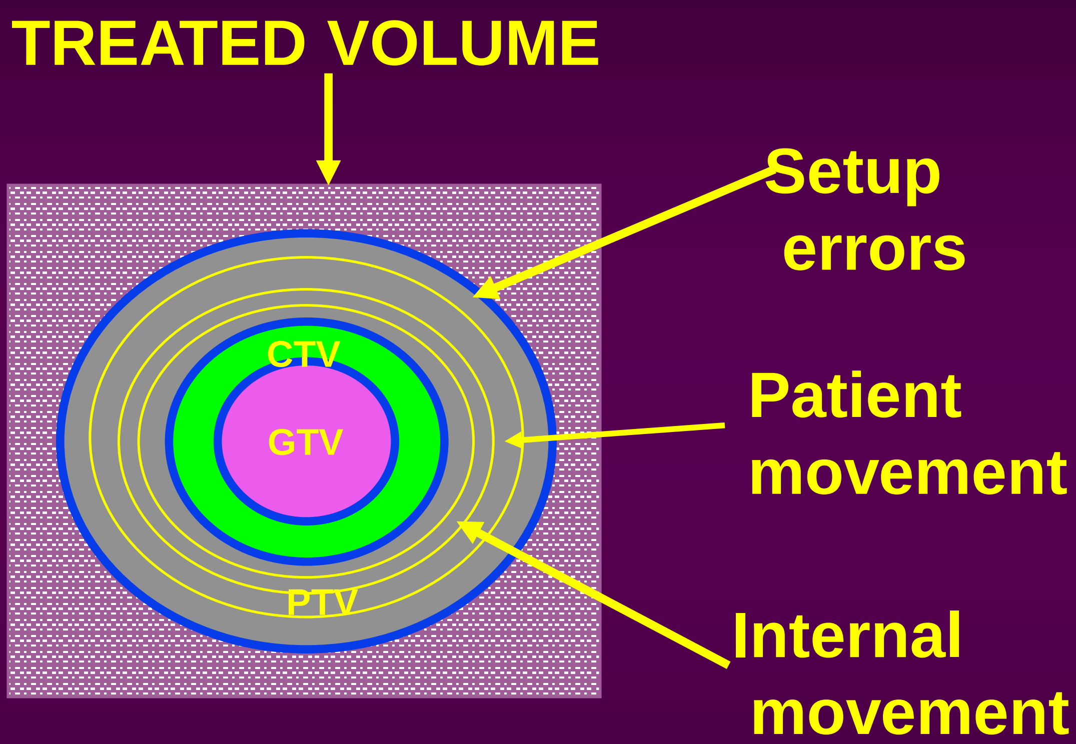
Brachytherapy in Combination with:

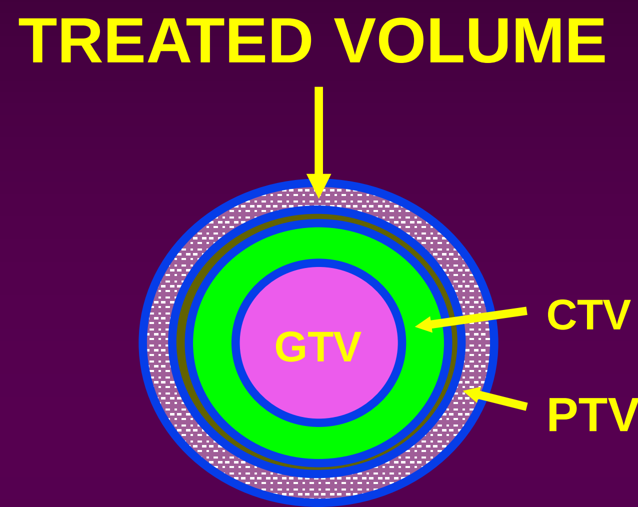
- EBRT to treat LN, shrink tumor; brachy to boost gross tumor
- Surgery to debulk; brachytherapy treats microscopic margins
- Chemotherapy for radiosensitization, micrometastasis, debulking

Relative Contraindications for Brachytherapy

- Large or diffuse tumors
  - but can use to boost EBRT dose
- Metastatic disease
  - but can sometimes use for palliation
- Inaccessible tumors
  - but can use special techniques like IOHDR
- Poor medical condition
  - but can use percutaneous minimally invasive techniques

Treatment Planning
Determination of Target Volumes: EBRT VS BRACHY





EBRT

- Margin over CTV to account for:
  - —Internal movements
  - —Patient movement
  - —Setup errors

BRACHY

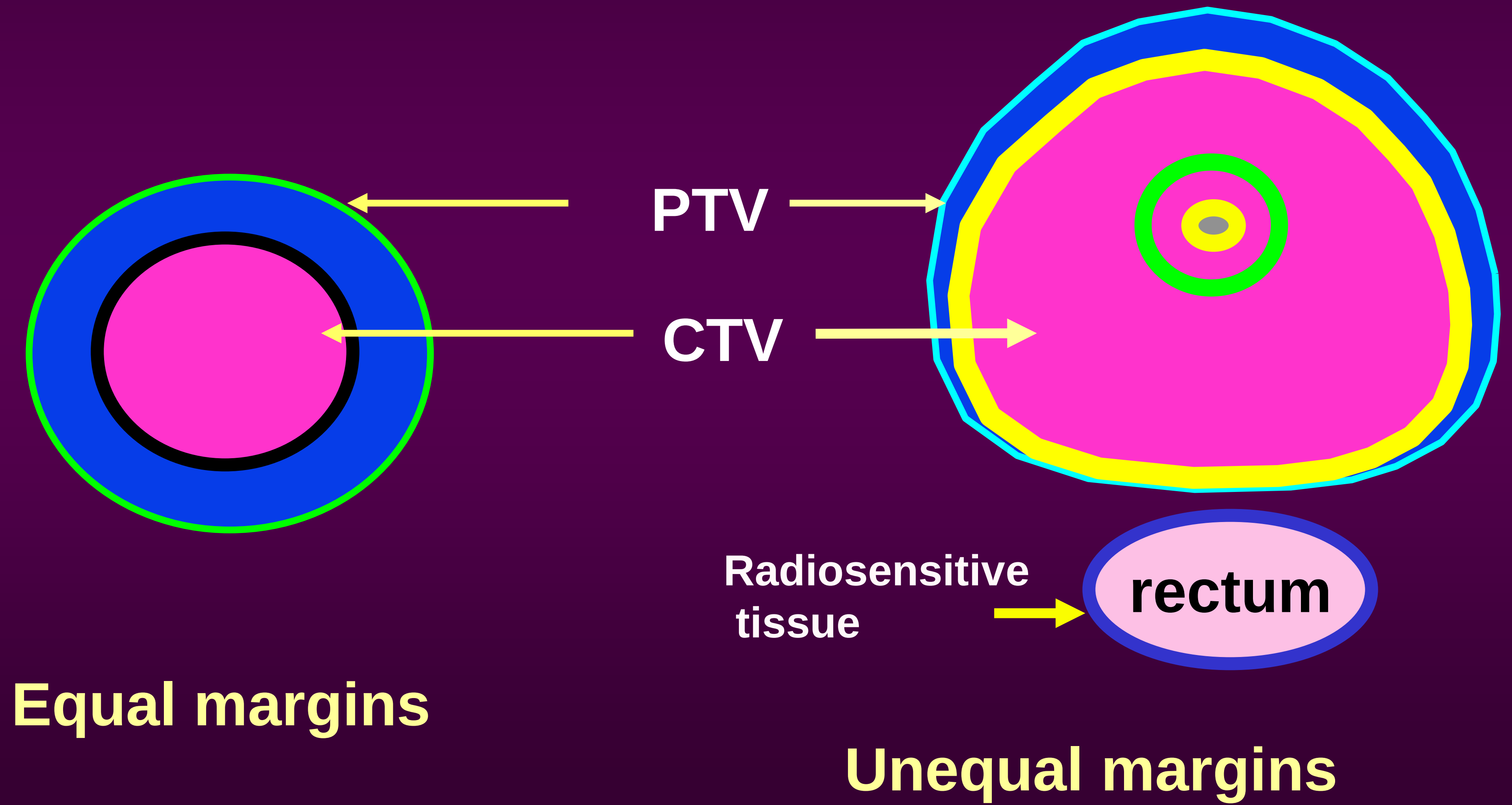
- Margin over CTV to account for:
  - —positional errors
  - —catheter movement
  - —tapering of isodose curve

Coverage of PTV

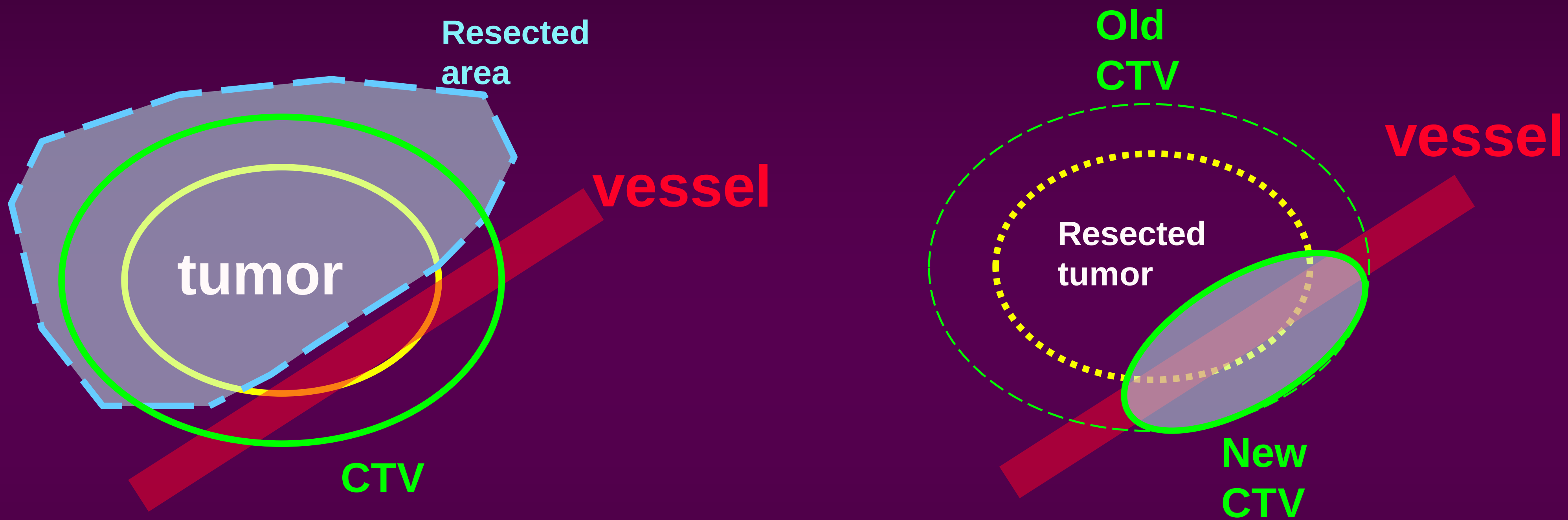
- Determine GTV using multiple modalities :
  - Clinical inspection, palpation
  - Imaging: X-Ray, CT, MRI, Ultrasound, PET
  - Endoscopy
  - Intraoperative
- Add margin for CTV
  - Clinical knowledge/judgment of patterns of spread
  - Radioimmunoguided (RIGS)
- Add margins for PTV
  - Type of brachytherapy modality

Treatment Planning: Margins

• Margins may be unequal to minimize risk of damage to critical normal tissues



Treatment Planning – effect of debulking surgery



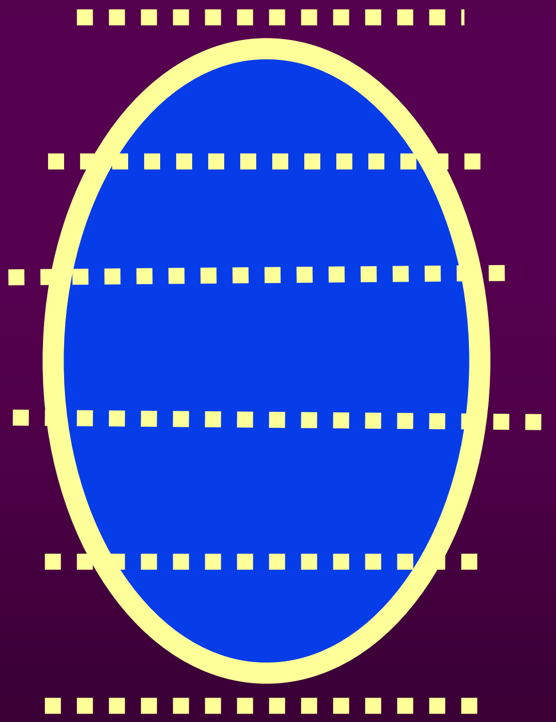
- Adjust CTV to account for other therapy (surgery, chemotherapy)

Treatment Planning –
Distribution of radioelements to cover PTV

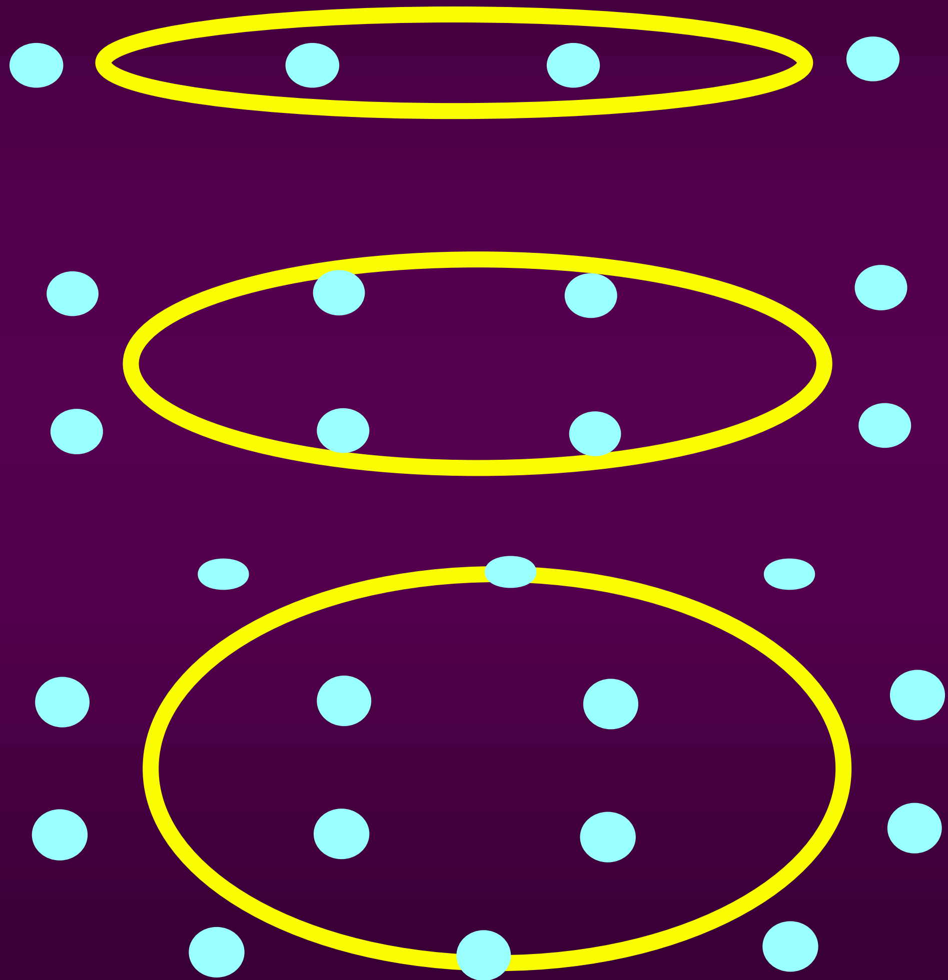
- Systems/Rules
  - Manchester (Patterson-Parker)
  - Quimby
  - Paris
  - Memorial
- Computerized preplan
  - Currently more common method

Planning - Interstitial

- Sources placed within tumor tissues
- Irradiates from all sides
- Less inhomogenous dose distribution
- Free hand or template
- Commonest site is prostate



Single, Double and Multiple Plane Implants

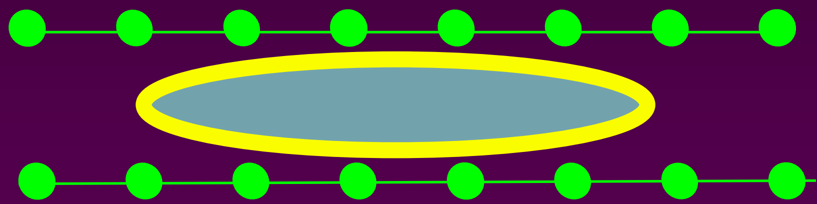


<1 cm thick - single plane

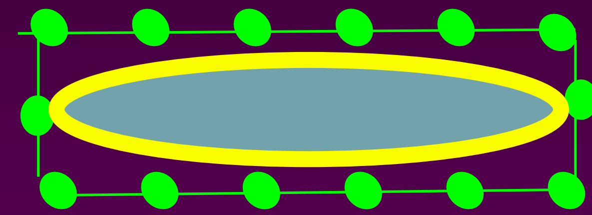
1-2 cm thick - double plane

>2 cm thick - multiple plane

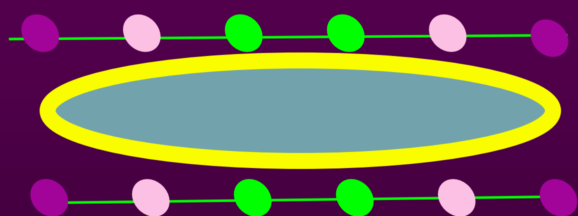
Adequate Coverage of Target Volume



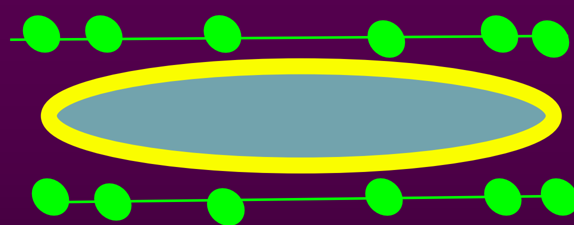
Equal spacing/equal weighting
Extend beyond target



Equal spacing/equal weighting
Crossing catheter

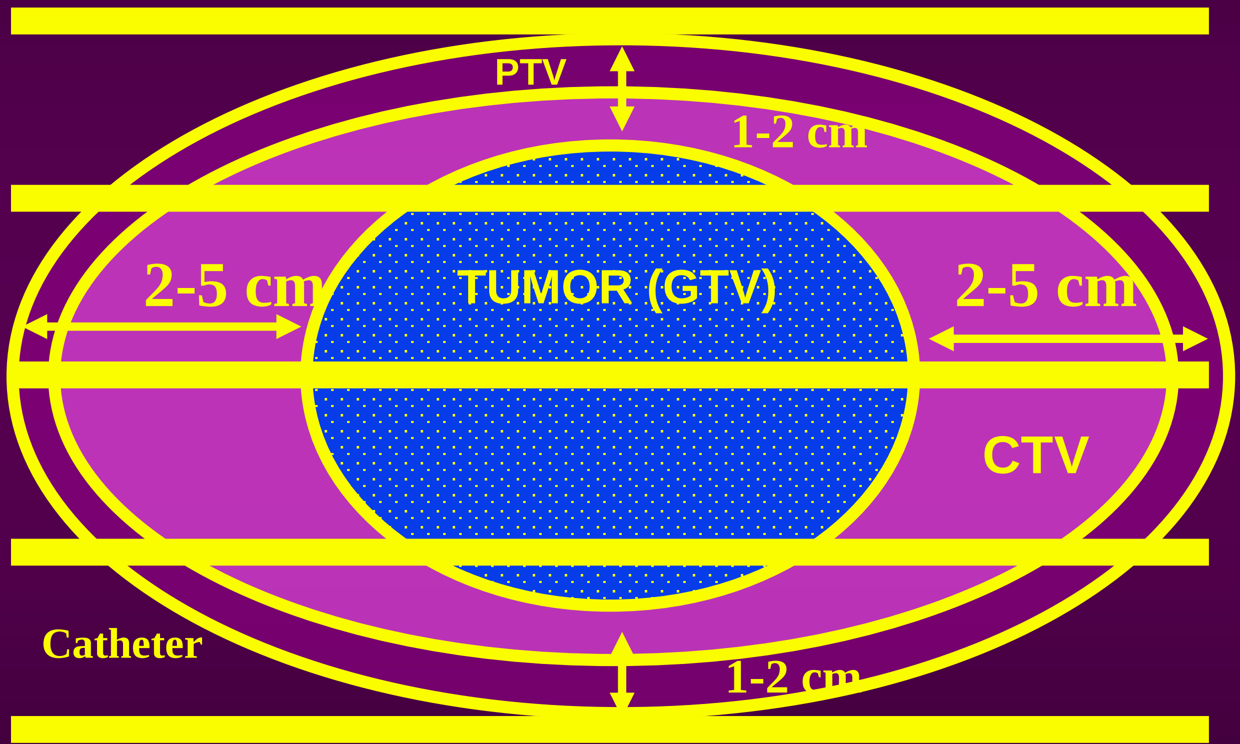


Equal spacing/differential weighting
or differential dwell times



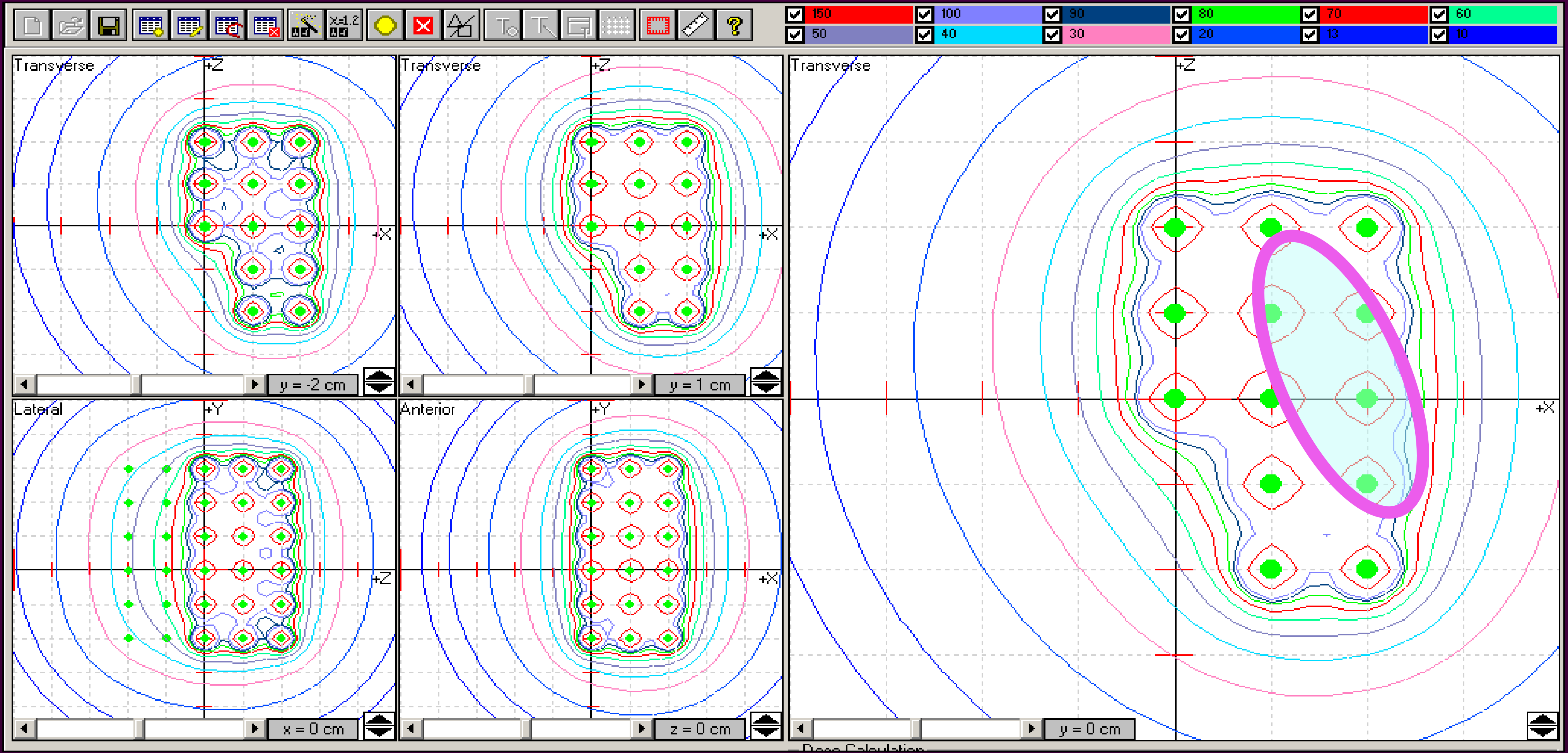
Equal weighting
/differential spacing

Preplan – single plane interstitial



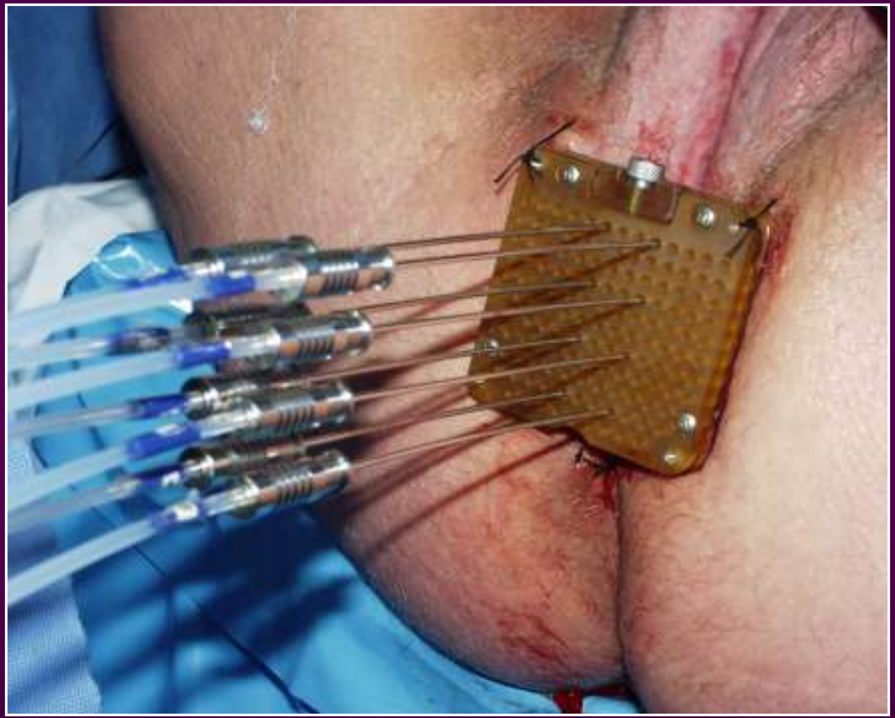
GTV = gross tumor volume; CTV = clinical target volume; PTV = planning target volume

Preplan – multiplane freehand interstitial



Interstitial multiplane - templates

- Space needles/catheters evenly, parallel (usually 1 cm apart)
- Holds needles firmly
- Syed, MUPIT, custom made, IOHDR
- GYN, prostate, rectum common sites



Interstitial GYN Preplanning

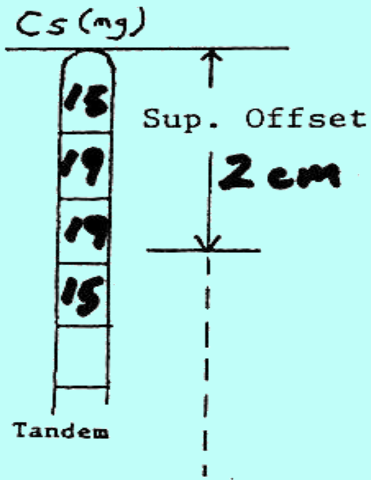
Diagnosis: ______________________
Site of Implant: Cervix
Planned Dose: 4,000 cGy
Tumor Dose Rate: 80-90 cGy/Hr.

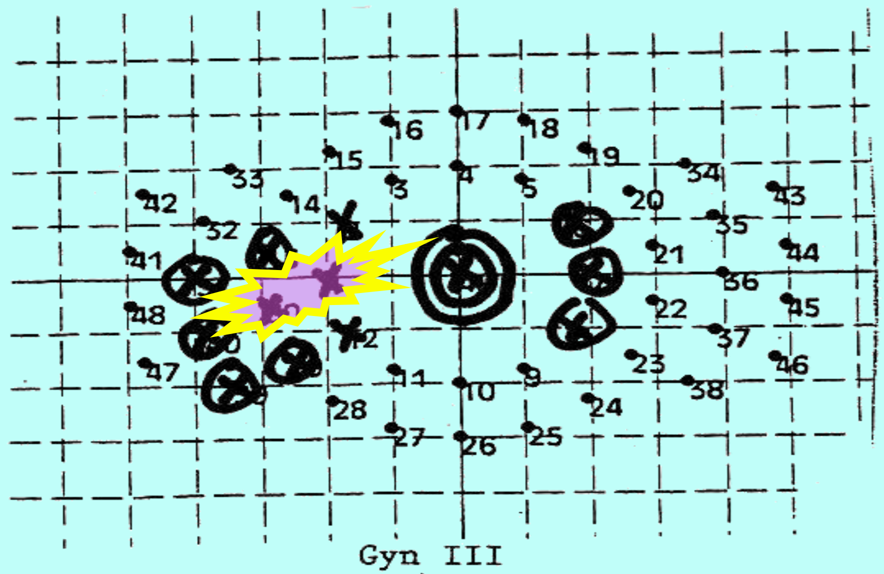
Planned Implant Date: ______________________
Radioisotope: Ir-192/Cs-137
Implant Duration: 42-48 Hrs.
Attending/Resident: ______________________

Loading Pattern: Template Nag I / Nag II / Gyn II / Gyn II; Central Ir/Cs

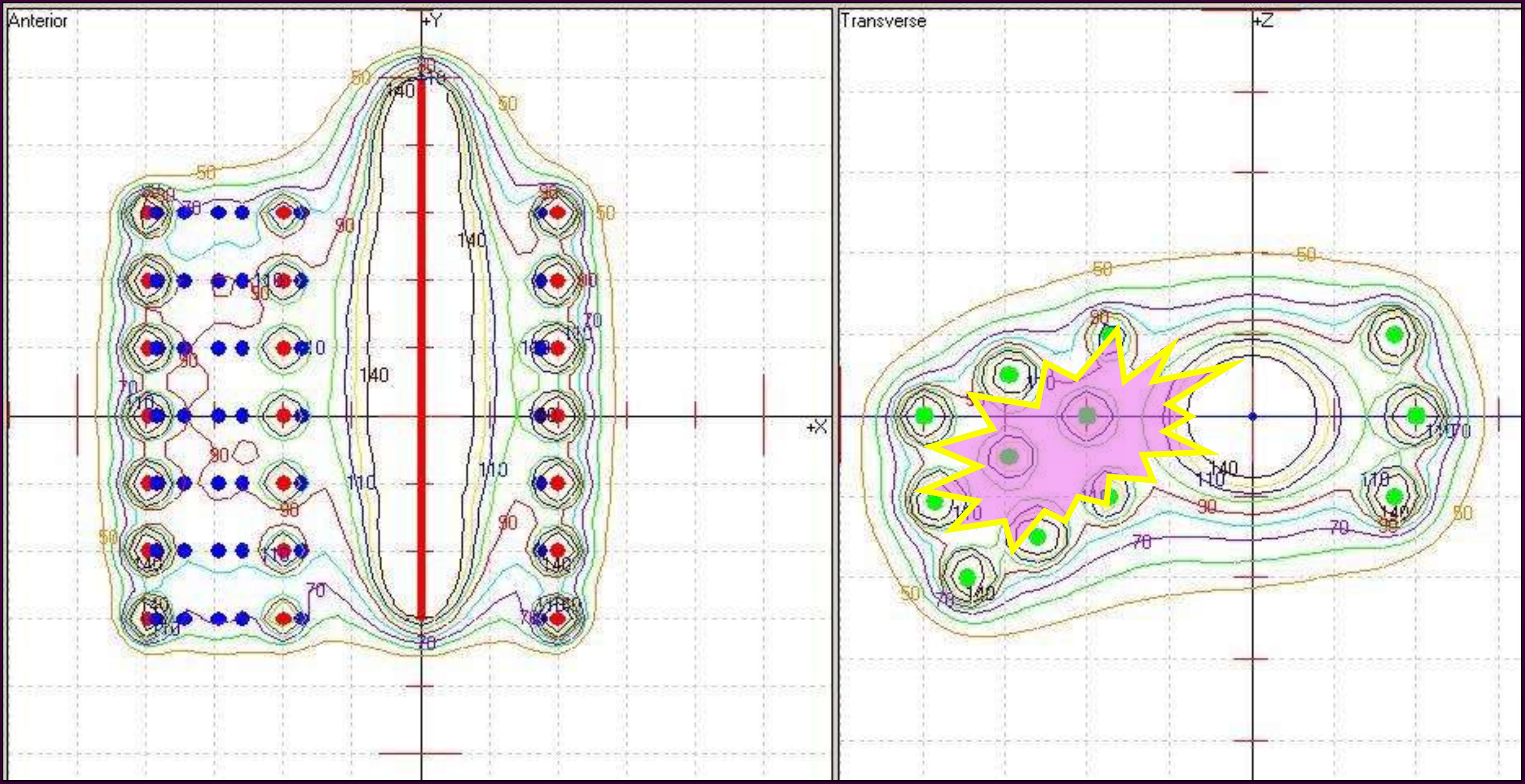
Tube #	1	2	6	7	8	12	29	30	31	39	40	49									
# Sources	6	→										4									
Length (cm)	5	→										8									
Activity (mCi)	.5	.5	1	1	1	.5	1	.5	1	1	1										
SupOffset (cm)												2									
Inf.Offset (cm)												0									

Note: Y=0 for the most inferior source.





Interstitial GYN Preplan



Interstitial IOHDR Gyn template

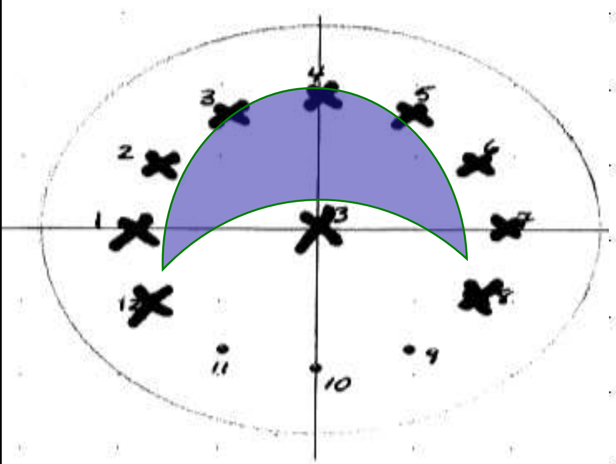
Name: ______________________ **RT#:** ______________________

Diagnosis: ______________________ **Planned Implant Date:** ____________

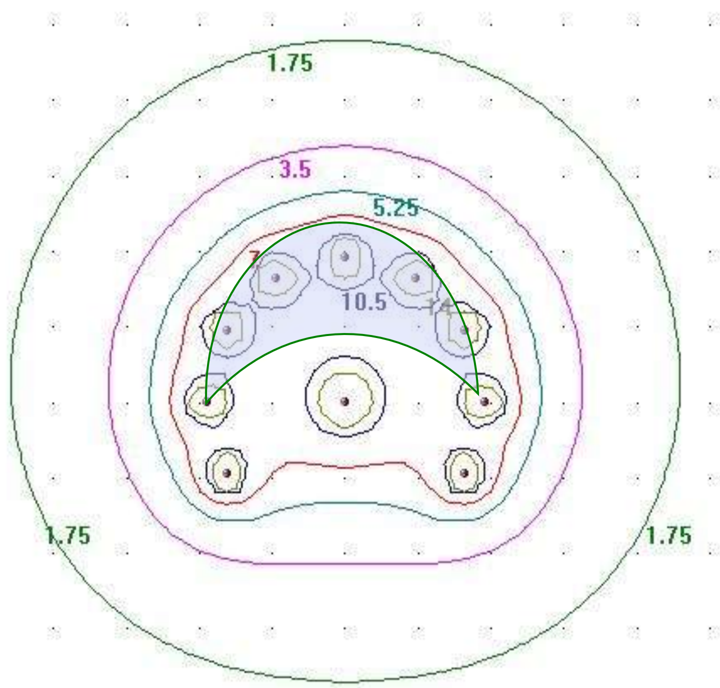
Site of Implant Vagina **Attending/Resident:** ____________

Dose per Fraction 700 cGy **No. of Fractions** 3

Needle #	1	2	3	4	5	6	7	8	12	13			
Treatment Length(cm)	6								→	7			
# of Dwell Points	13								→	15			
Dwell Weighting	2								→	4			
Distance Below Tip of Central Needle													



HDR # 2-13 Hole



- Equal dwell times preferred
- Easier QA
- Less chances of error
- Quick modifications possible

Preplan from nomogram

Dimensions	CT	US	
A-P	3·2		
R-L (LAT)	4·8		
SUP-INF	4·0		
L+B+H	12·0		
A.D.	4·0		
A.D. + 1	5·0		
U	216		
If EBRT U*0.75			
U/Seed	2·4		
# seeds	90		
Volume (cc)	32		

PSA: 6·8 GLEASON: 3+3=6

Dose Intensification: RT LT Lobe

Previous TURP : NO

Previous Hormones: NO

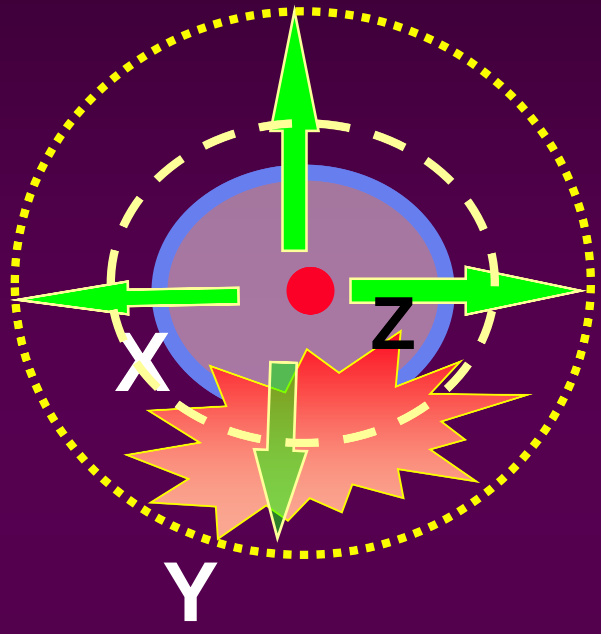
Previous XRT: NO

Concurrent XRT: NO

3.1	58	75
3.2	63	81
3.3	67	86
3.4	71	92
3.5	76	98
3.6	81	105
3.7	86	111
3.8	91	118
3.9	97	125
4	102	132
4.1	108	139
4.2	114	147
4.3	120	155
4.4	126	163
4.5	132	171
4.6	139	179
4.7	146	188
4.8	152	197
4.9	159	206
5	167	216
5.1	174	225
5.2	182	235
5.3	189	245
5.4	197	255
5.5	205	266
5.6	214	276
5.7	222	287
5.8	231	298
5.9	239	309
6	248	321
6.1	257	333
6.2	267	345

Planning – intracavitary

- Irradiates from inside outwards in all directions
- Limitations in source positioning in relation to tumor
- Doses more inhomogeneous
- Deeper parts of tumor (Y) may get less than prescr. dose (X)
- Some normal mucosa (Z) may get much higher dose than prescription point (X)
- eg gynecological, nasopharynx

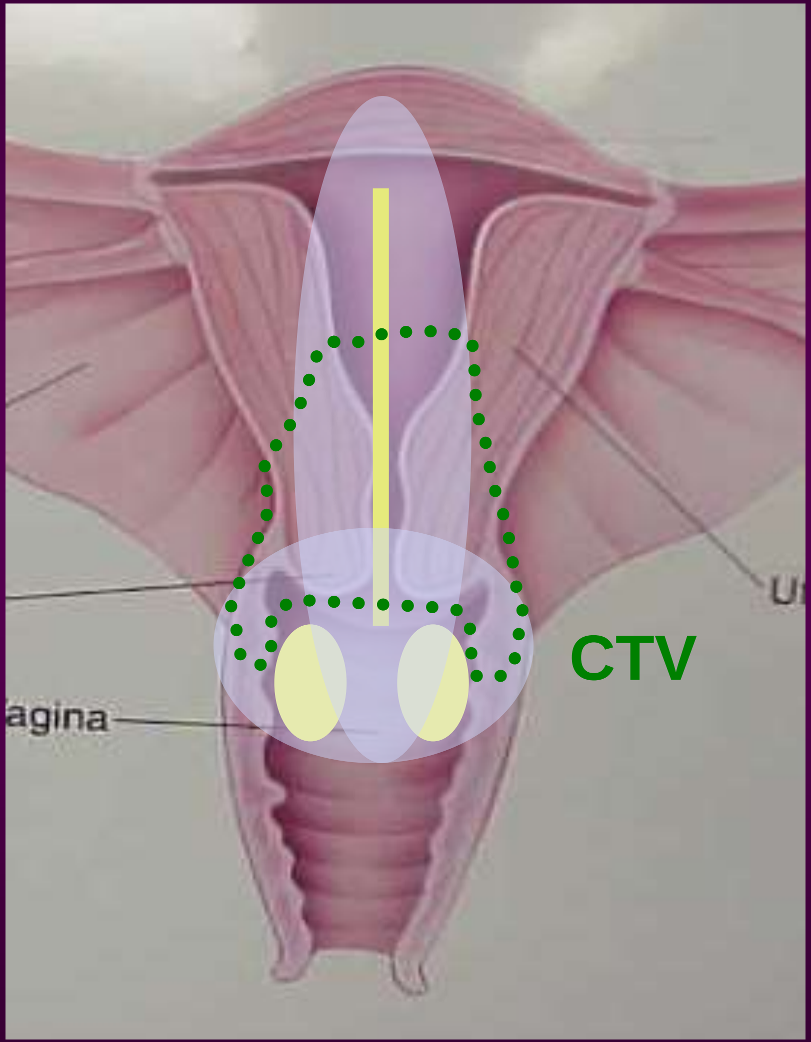


Planning - Gyn Intracavitary

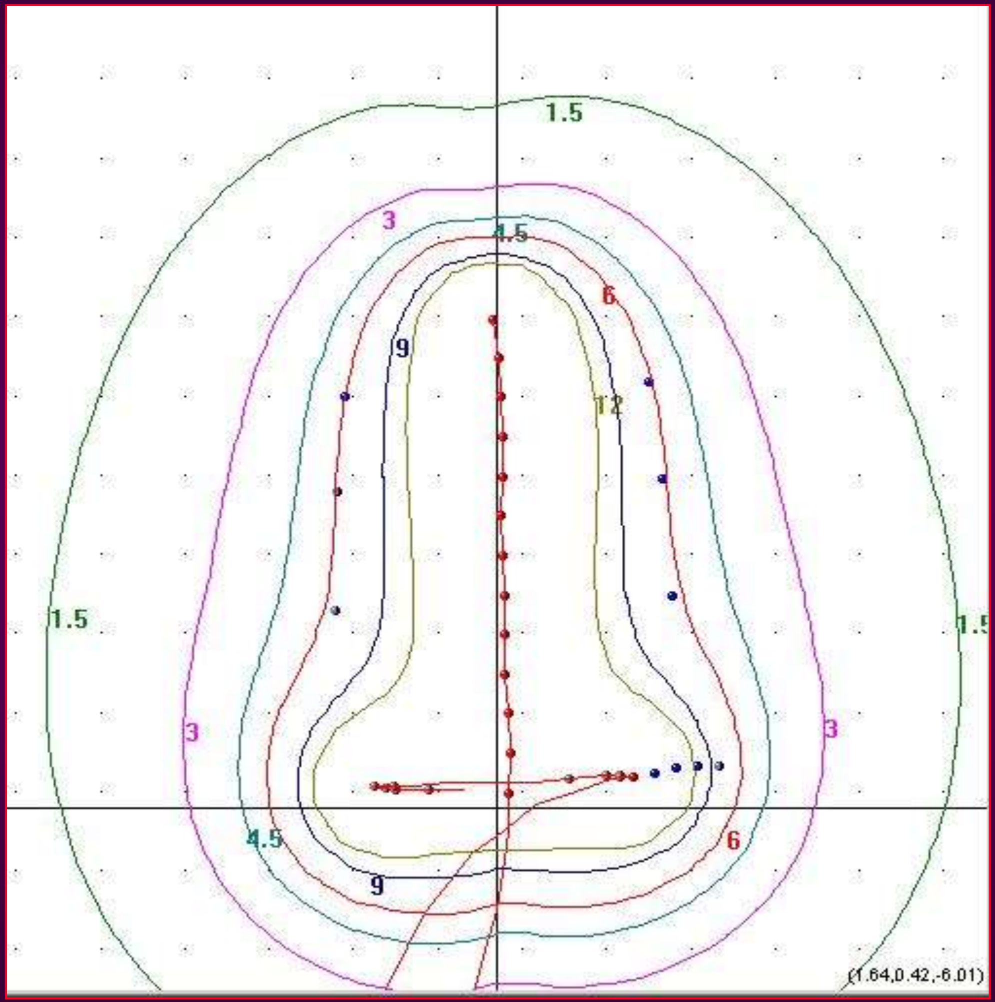
- Initial EUA, f/u pelvic exams, CT/MRI for defining CTV
- EBRT first to shrink tumor & irradiate nodes
- Higher EBRT dose for larger tumors
- 1-2 LDR; 2-5 HDR applications
- Minimize total treatment time

LDR Gyn Intracavitary

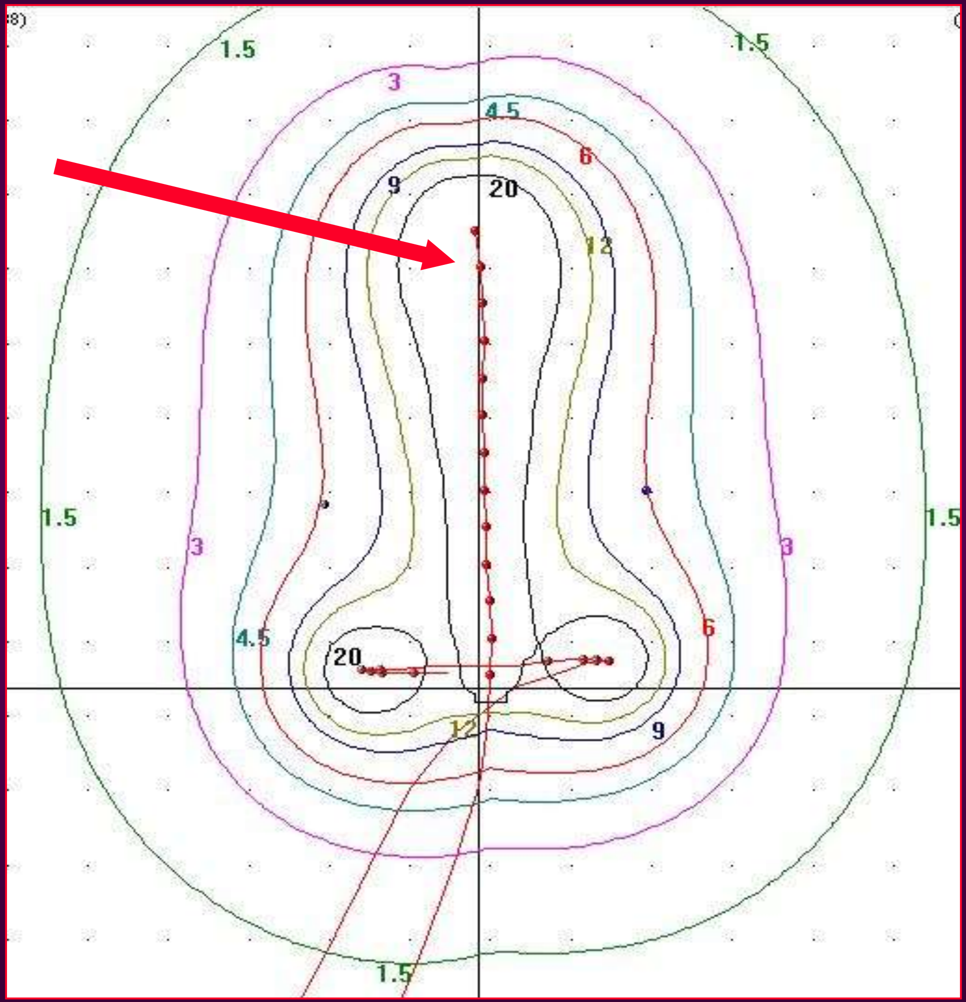
- Choose suitable applicator
  - Tandem & ovoids (T&O)
    - Fletcher-Suit T&O
    - Henschke T&O
    - Ring & tandem
  - Delclos cylinder & tandem
- Interstitial if unsuitable for intracavitary
  - Bulky param; extensive vaginal; no cervical canal; poor vaginal anatomy; prior XRT



Intracavitary Preplan

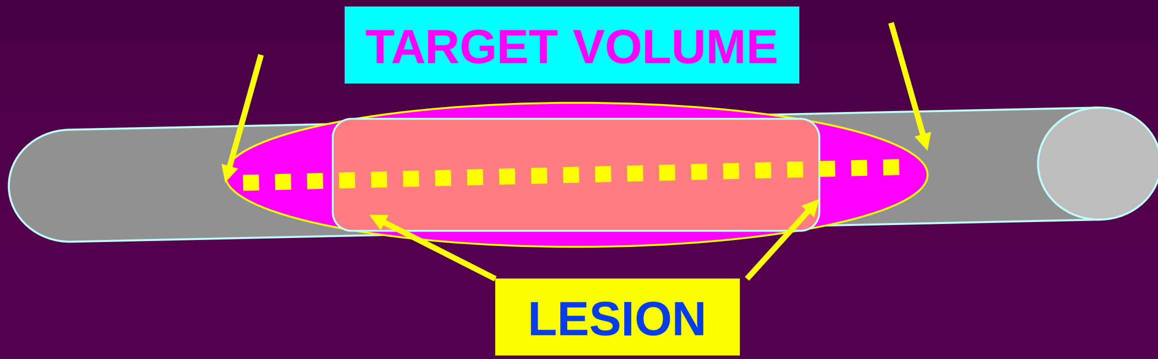


Pear shaped distribution



Poor dose distribution

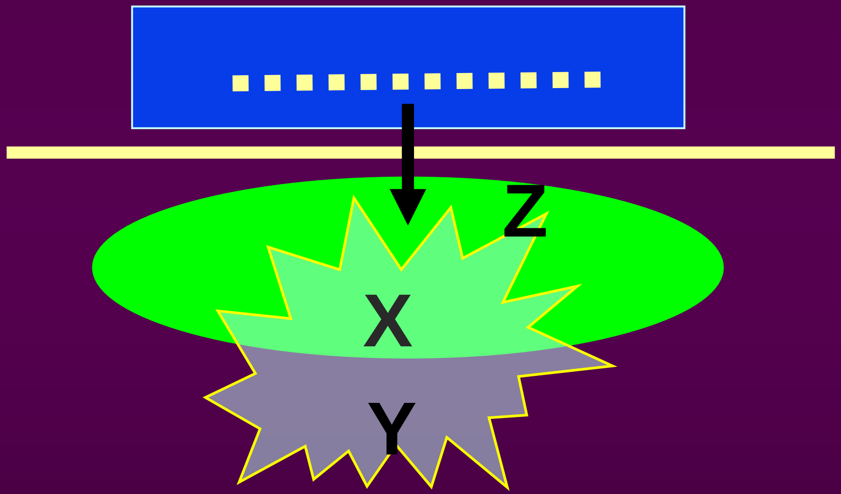
Planning –intraluminal



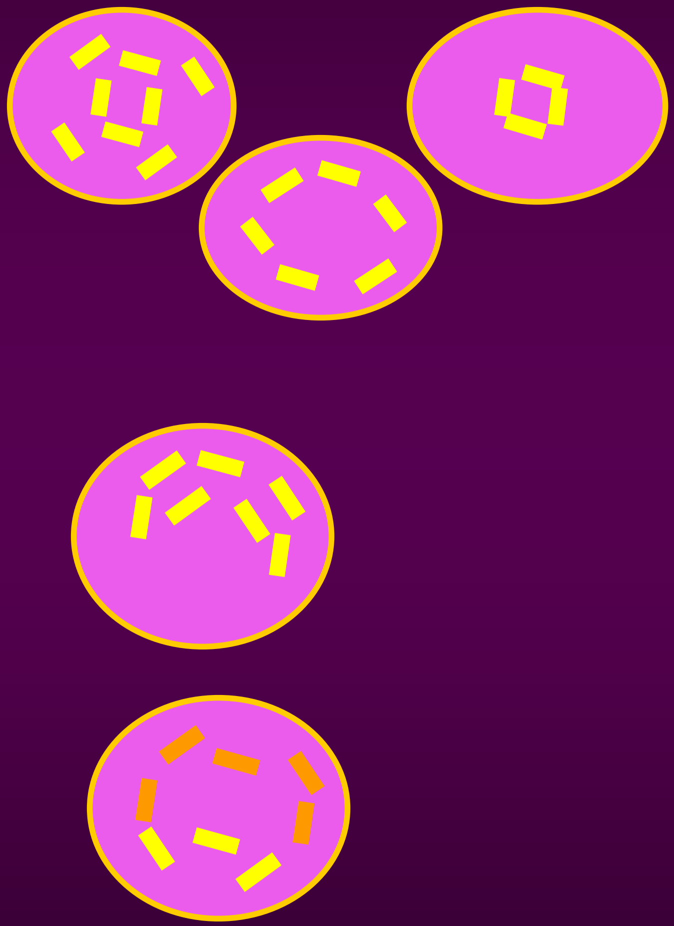
- Subcategory of intracavitary
- Planning considerations similar to intracavitary
- Margins considerations are longitudinal rather than radial
- Eg. esophagus, endobronchial, intravascular

Surface application/plaques

- Irradiation from one side
- Inhomogeneous dose
- Relationship of tumor (Y), normal tissue (Z) to dose prescription point (X) very important



Surface application – eye plaque

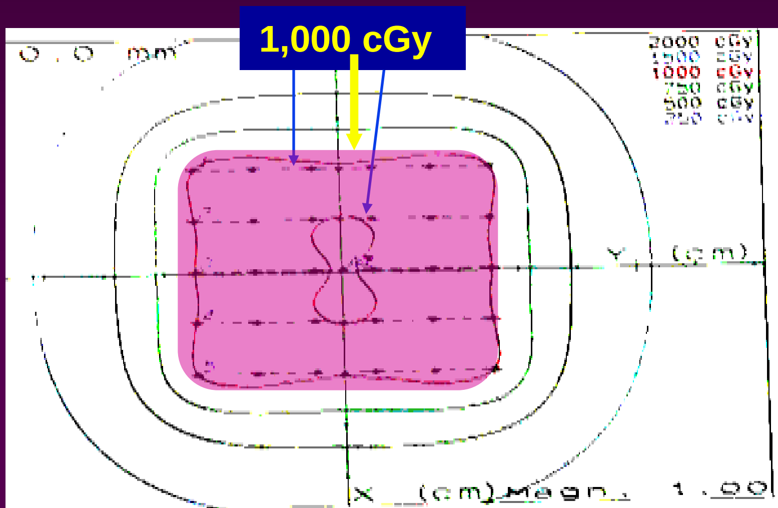


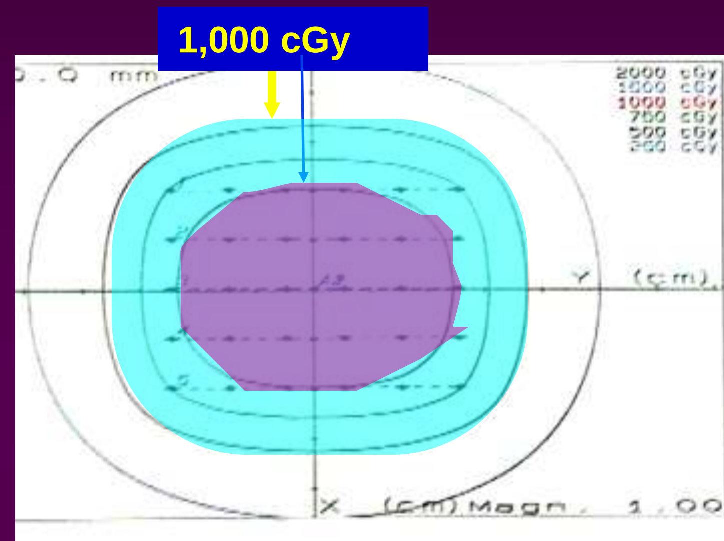
- Preplan done to deliver 8500 cGy to tumor apex in 4 days
- Arrangement of seeds within plaque
  - Central vs peripheral vs uniform
  - Symmetrical vs non-symmetrical
  - Uniform activity vs differential activity

IOHDR surface application

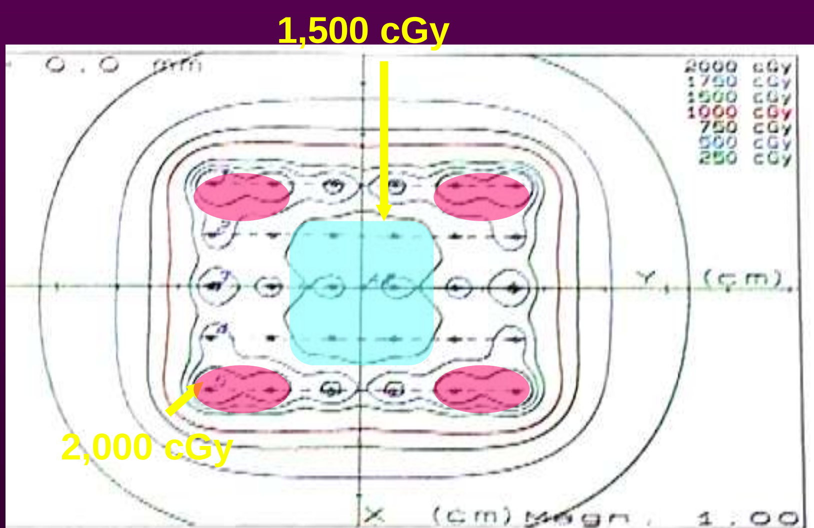
Optimized

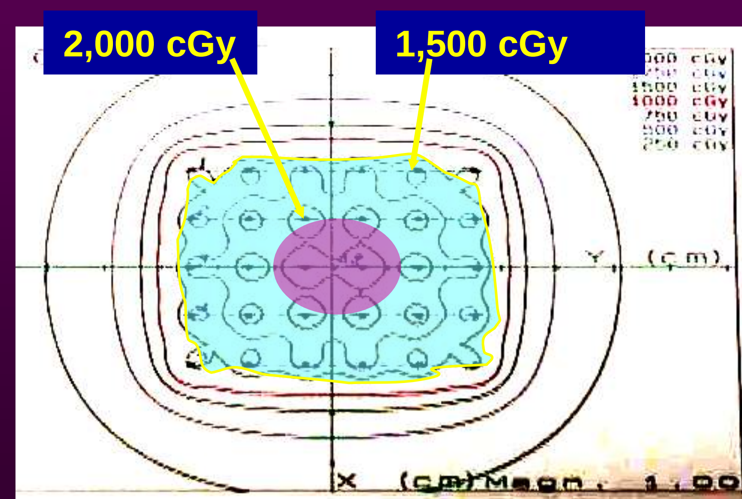
Equal dwell weights





At 0.5 cm depth





On surface

Planning: Dose Rates (ICRU #38)

- Low dose rate (LDR) - 0.4 to 2.0 Gy/hr
- Medium dose rate (MDR) - 2 - 12 Gy/hr
  - also called intermediate dose rate;
  - rarely used because of high exposure if manually loaded
  - outpatient therapy not possible, even if remotely loaded
- High dose rate (HDR) - >12 Gy/hr
  - usually 100 - 300 Gy/hr
  - only by remote loading
  - outpatient treatment possible

Modality - LDR vs HDR

- History of previous treatment
  - If normal tissue received ≅ tolerance, then LDR preferable
- Need for precision delivery of the dose
  - Protect sensitive structures by optimizing dose dist by HDR
- Patients medical condition/nursing requirements
  - If intensive nursing required HDR may be preferable
- Cost
  - In-pt hospitalization cost for LDR vs HDR equipment cost

Advantages / Disadvantages of HDR

- Outpatient treatment possible
- No personnel exposure
- Easier & more precise dose distribution optimization
- More precise delivery through immobilization
- Can Tx patients with intercurrent medical conditions
- Higher normal tissue effect for tumor isoeffect doses (lower therapeutic ratio) unless fractionated and normal tissue displaced
- Higher probability of executing error before detection
- Greater time & personnel requirements

Planning: Permanent vs. Temporary

Permanent

- Implanted into tumors and allowed to deliver radiation over a period of time
- Not removed

Temporary

- Placed in applicators
- Removed after therapy

Permanent brachytherapy

- Simple procedure; outpatient therapy;
- Dose/distribution cannot be changed
- Palliative treatments/ deep seated tumors
- More comfortable & less chance of infection
- Short $T^1/_2$ isotopes (Au-198, Rn-222) brief isolation or low energy isotope (I-125, Pd-103) no isolation
- Sources may migrate: $\therefore$ greater uncertainty
- Prostate most common organ

Temporary brachytherapy

- More precise control of dose/distribution
- Use longer $T^{1}/_{2}$ - Ir-192, Cs-137 (Ra-226)
- Usually isolation during treatment
- Less comfortable, more time consuming.
- Use in curative cases
- Gyn, H&N, Sarcomas most common sites

Planning: Radioisotopes

Isotope	Half-life	Energy (MeV)	HVL (cm Pb)
Cobalt-60	5.26 yrs	1.25	1.2
Cesium-137	30 yrs	0.661	0.6
Iridium-192	74 days	0.350	0.4
Gold-198	2.7 days	0.412	0.3
Radon-222	3.8 days	0.83	0.8
Radium-226	1622 yrs	0.83	0.8
Iodine-125	60 days	0.028	0.003
Palladium-103	17 days	0.021	0.001

- Half life determines dose rate, period of irradiation
- Radiation energy determines coverage & radiation safety

Execution of Planned Treatment

- Reproduce preplan and modify if reqd.
  - Surgical exposure
  - Real time image guidance
  - Clinical (inspection, palpation)
  - Templates can aid to keep needles parallel
- Proper immobilization of patient during tx
  - Ensure applicator position changes minimally over the duration of therapy

Treatment Planning - dose

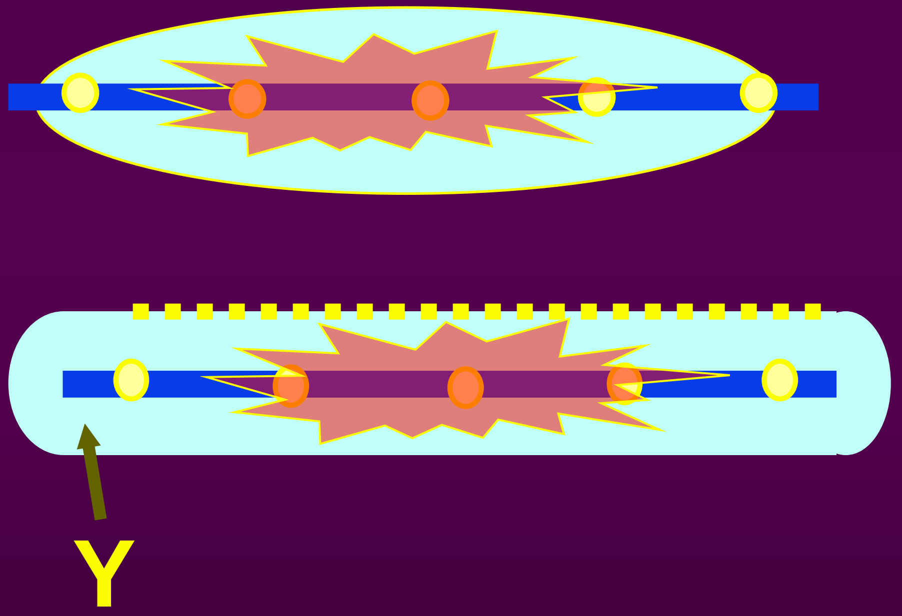
- Dose prescription
  - to a point or surface or volume
- Dose selection
  - dose to tumor
  - tolerance of normal tissues
- Dose reporting
  - at tumor; at critical normal tissues
- Dose optimization
  - appropriate optimization methods

Dosimetry Optimization

- Vary the strength of individual sources, dwell times, or source positions in order to produce a desired dose distribution
- Optimization based on rules (pre-computerization)
- Optimization based on trial and adjustment
- Computerized Optimization
  - based on geometry
  - based on specified dose points
  - inverse planning

Optimization

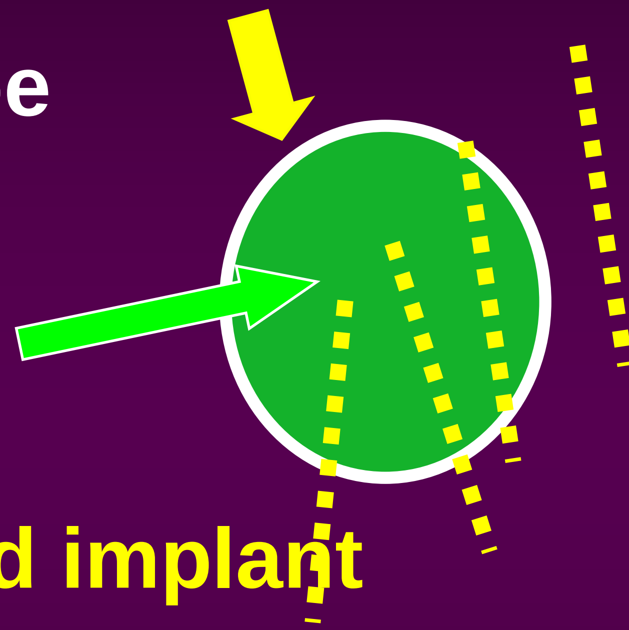
- Equal dwell time - higher dose in center vs periphery
- Optimized - homogenous dose at 1 cm, but higher dose at periphery of lumen (Y) where there is no tumor



Nag S: Pitfalls of inappropriate Optimization
J Brachy Int. 2000; 16:187-198

Optimization - WARNING!

- Optimization should not be a substitute for good placement



- Optimization makes a good implant better, but does not make a bad implant good!

Sites Implanted by Brachytherapy

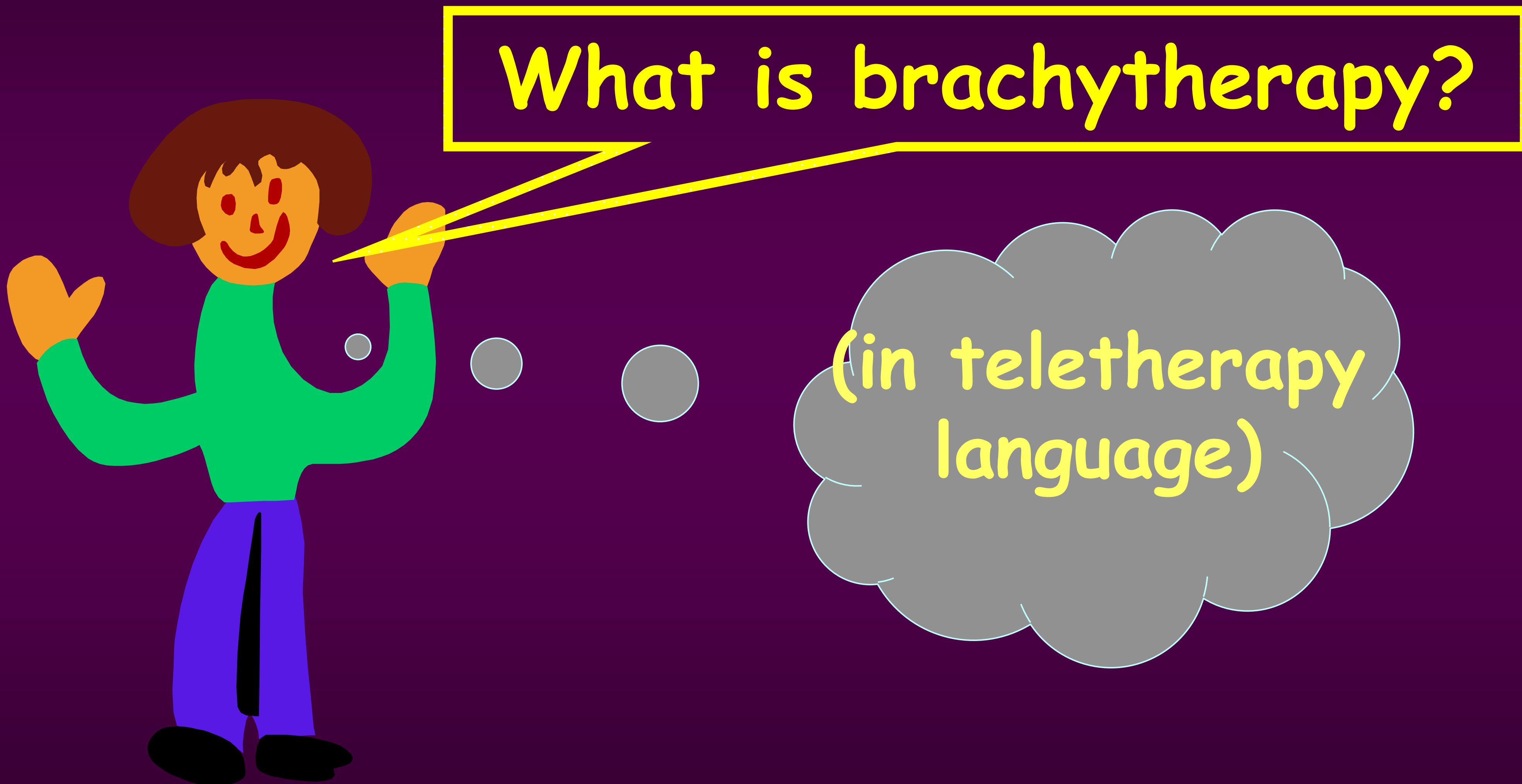
Common Sites (U.S.):

- Prostate
- Vascular
- Cervix
- Endometrium
- Lung
- Head & Neck
- Esophagus

Uncommon Sites:

- Eye
- Biliary
- Brain
- Bladder
- Breast
- Colorectal
- Sarcomas
- Pancreas
- Pediatric

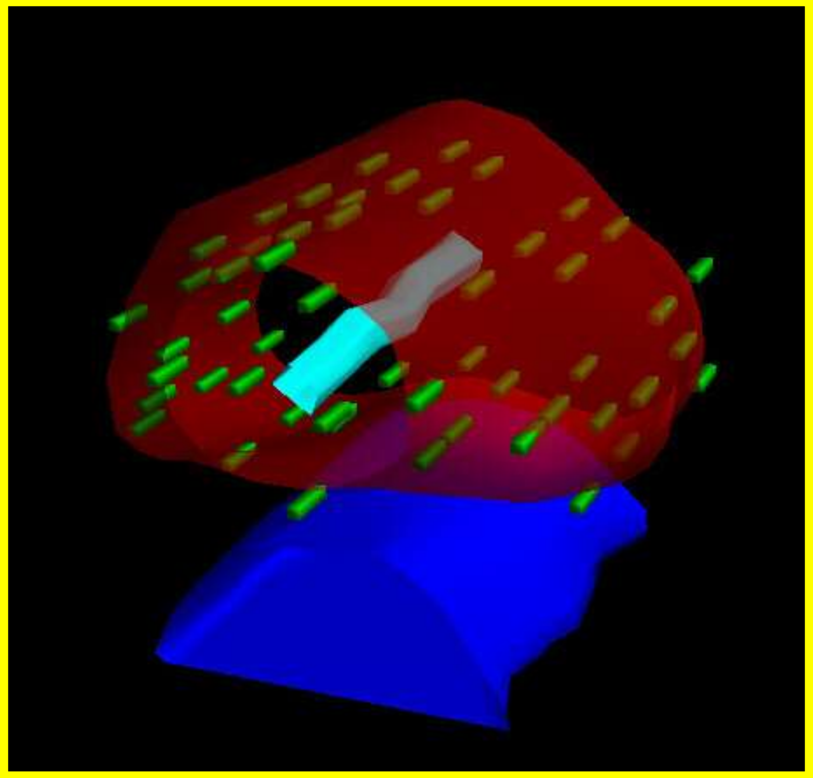
S U M M A R Y

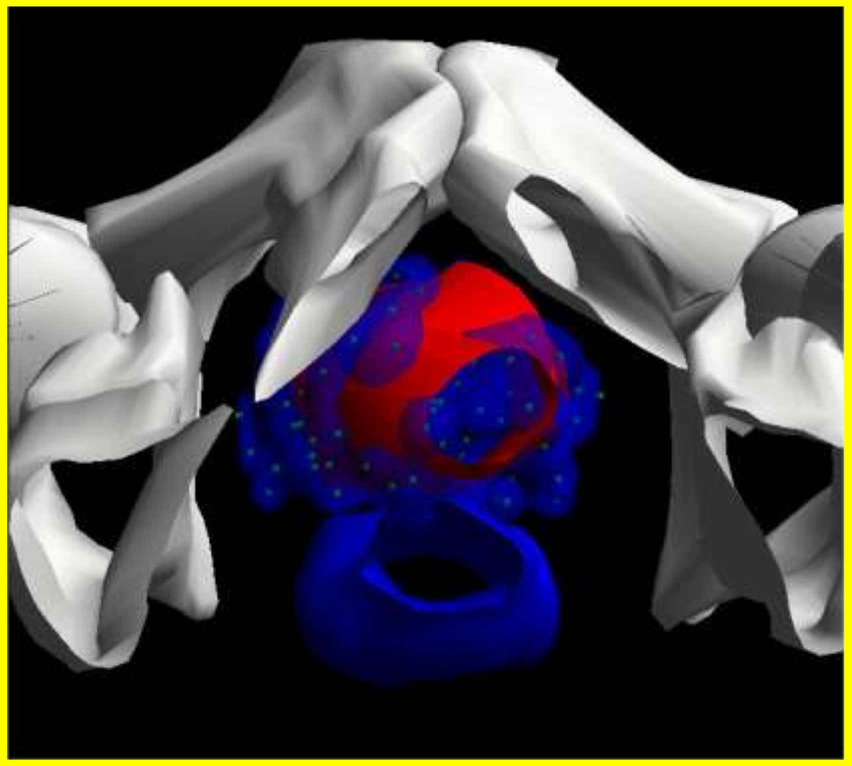


3 dimensional conformal radiotherapy

Brachytherapy isodose conforms to the shape of the tumor/target

Brachytherapy is the ultimate conformal therapy

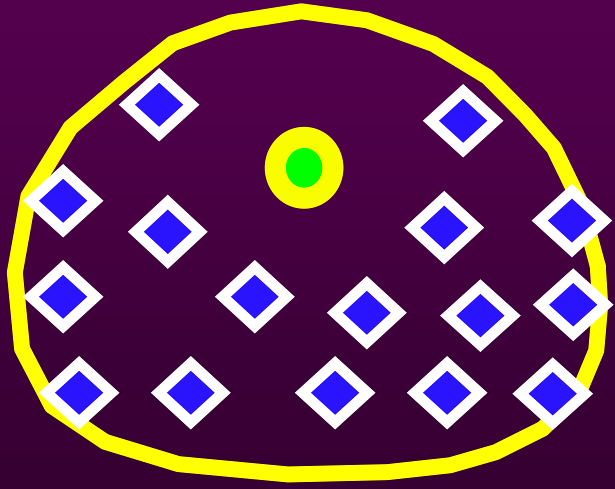


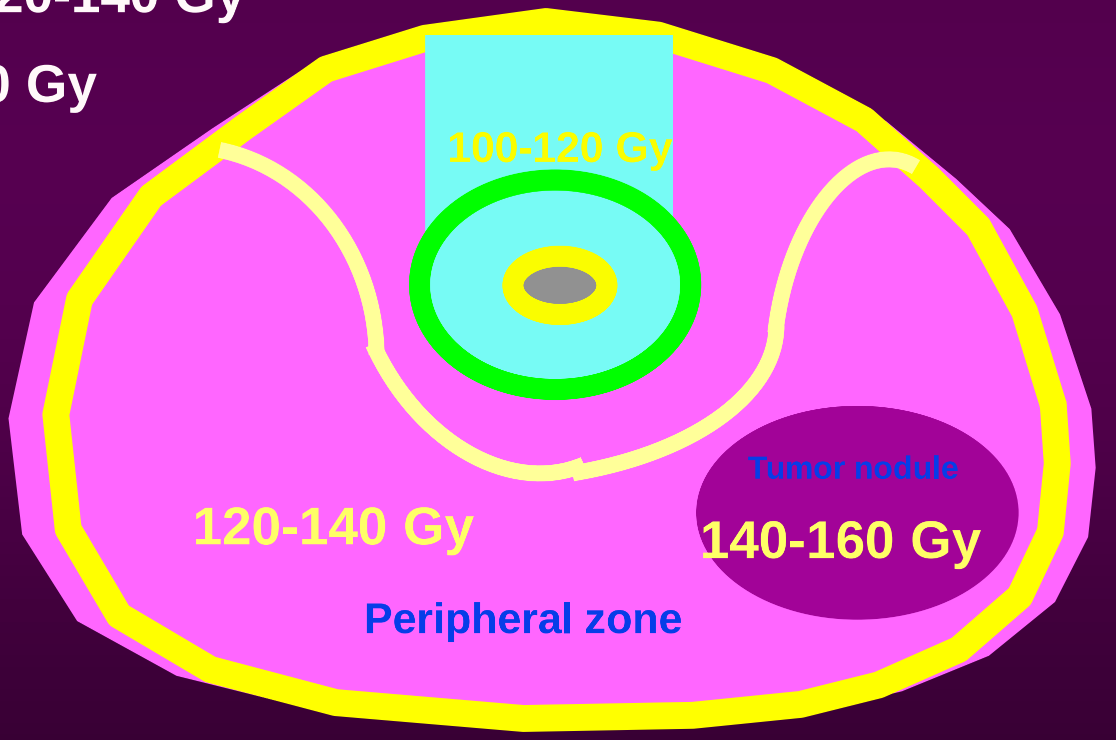


Intensity modulated radiotherapy (IMRT)

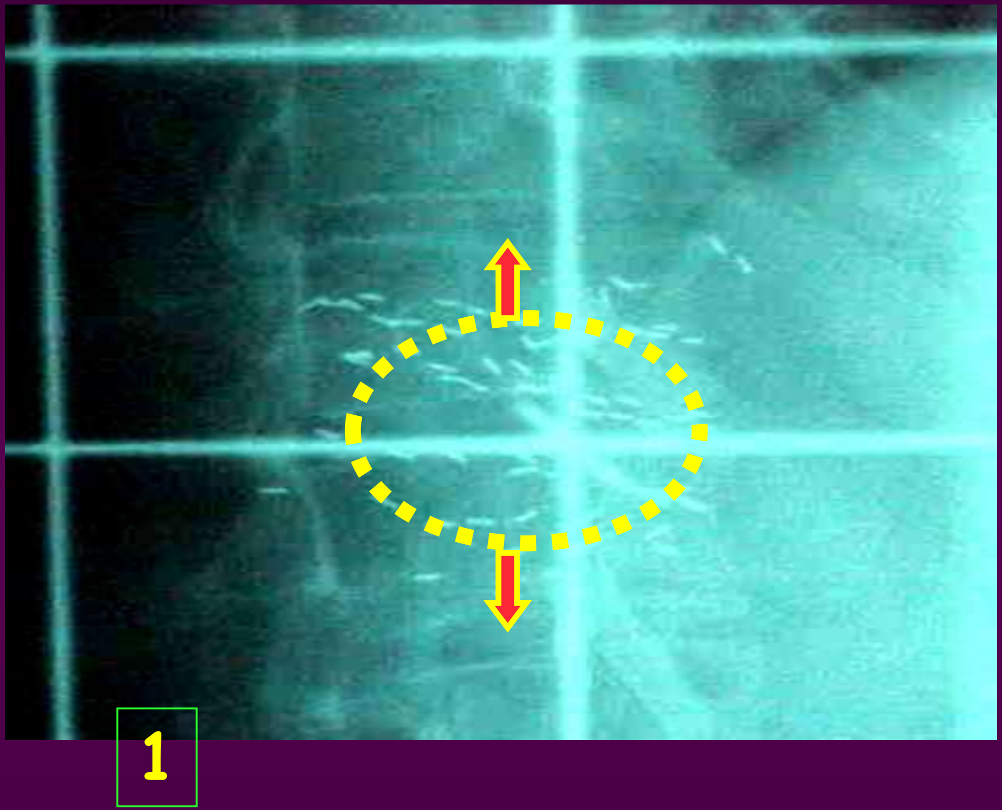
One can get very fancy and intensity modulate as in this example:

- ♦ Left lobe nodule (tumor) - 140-160 Gy
- ♦ Peripheral zone (microscopic) - 120-140 Gy
- ♦ Ant. Prostate (no tumor) - 100-120 Gy
- ♦ Urethra (no tumor) - 100-120 Gy

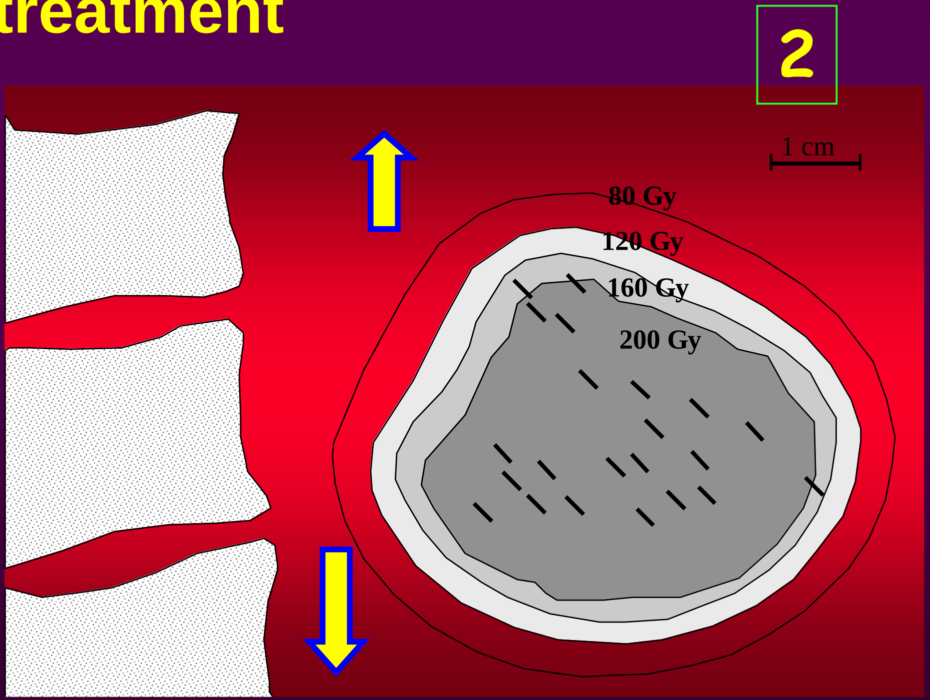




Respiratory-gated brachytherapy



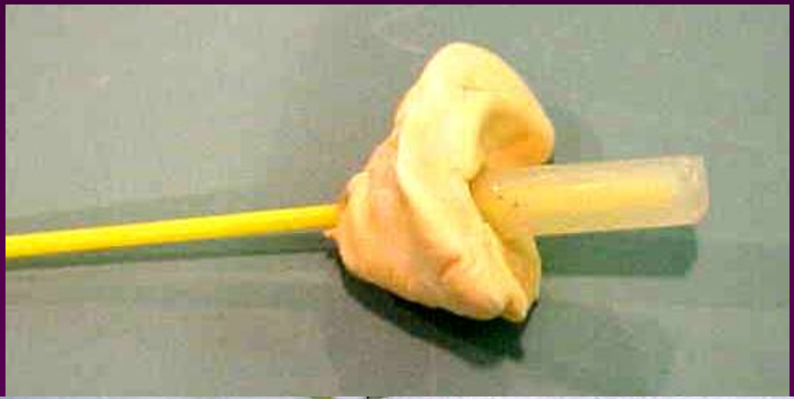
•I-125 seeds moves with the movement of the tumor, producing a respiratory-gated treatment

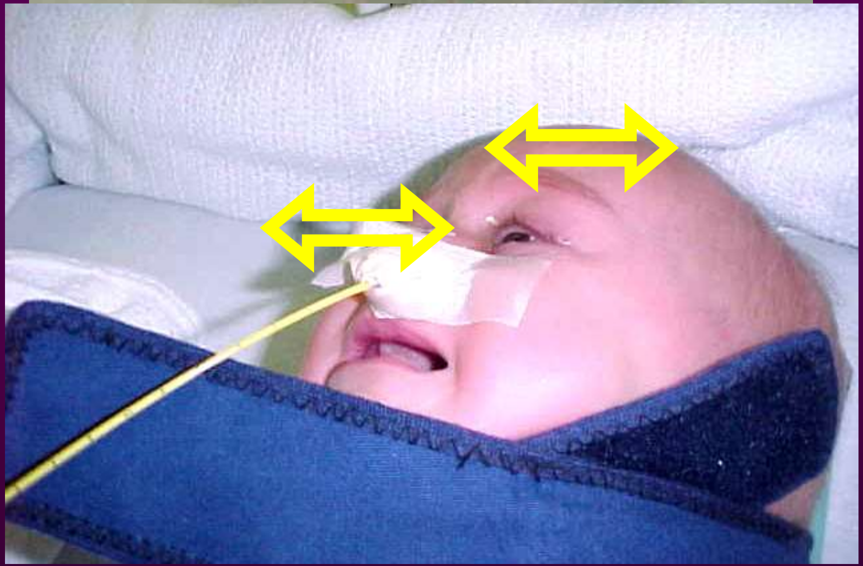


•Patient with I-125 seeds implanted in liver tumor.
•Tumor moves with respiration.

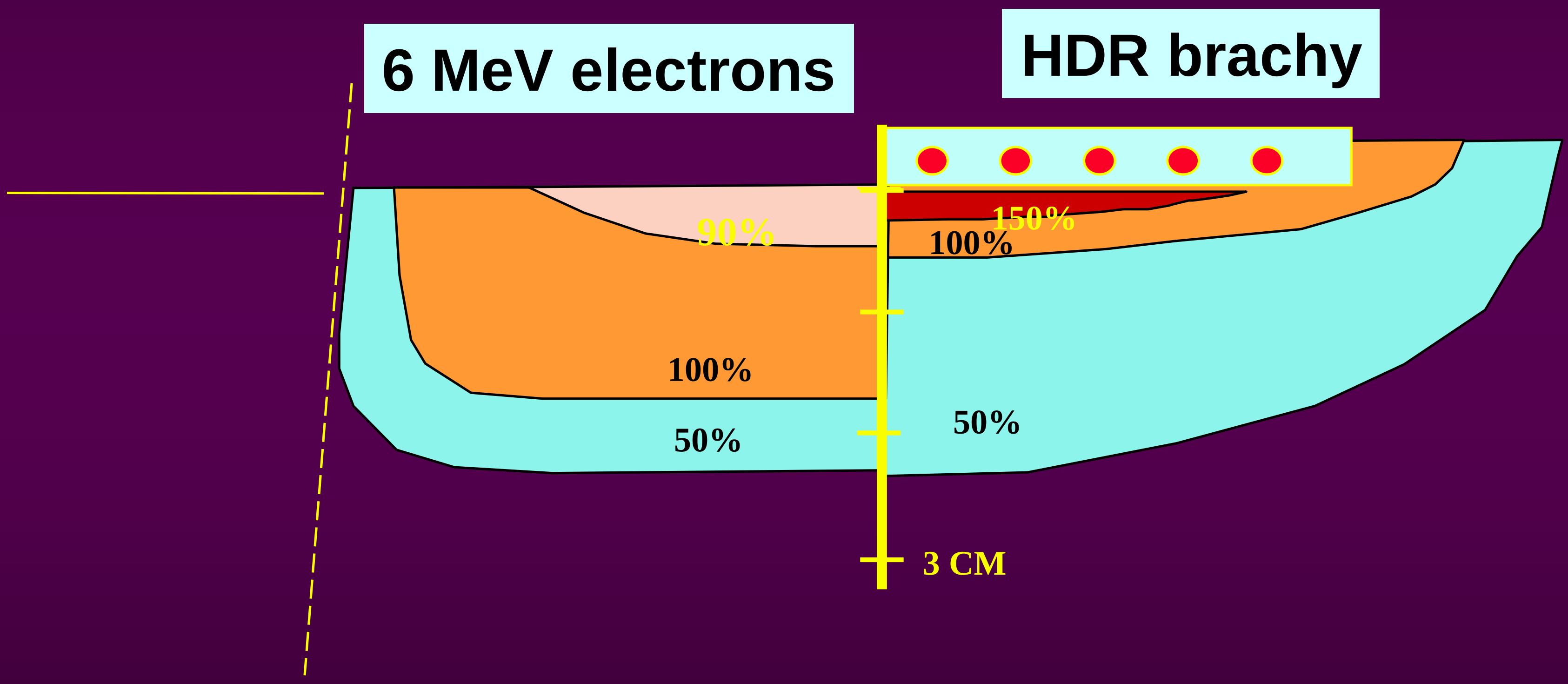
Tumor tracking brachytherapy

- Mold placed in nasal cavity of baby
- Baby immobilized in papoose board and neck brace without anesthesia
- Head might move slightly, but mold also moves such that mold is always in contact with tumor



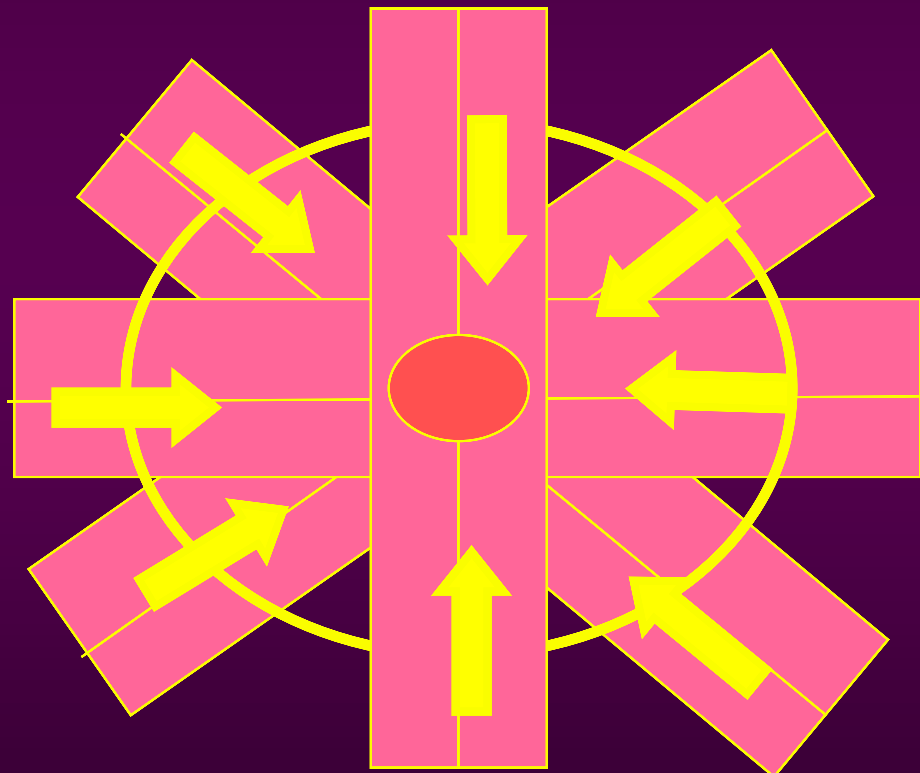


Limited penetration (like electron beam)



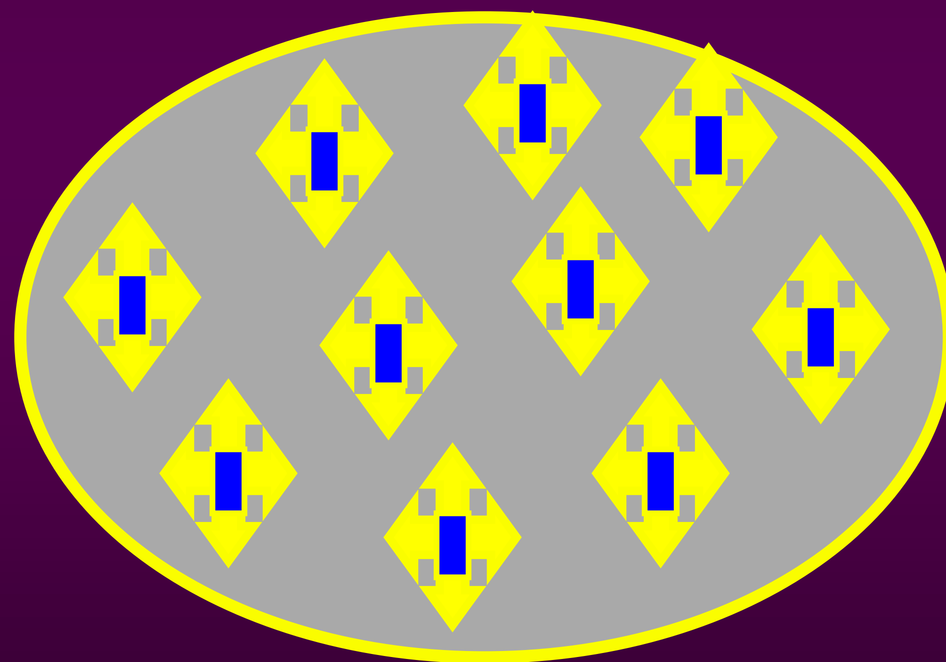
Multi-field therapy

EBRT (8 FIELDS)



BRACHY

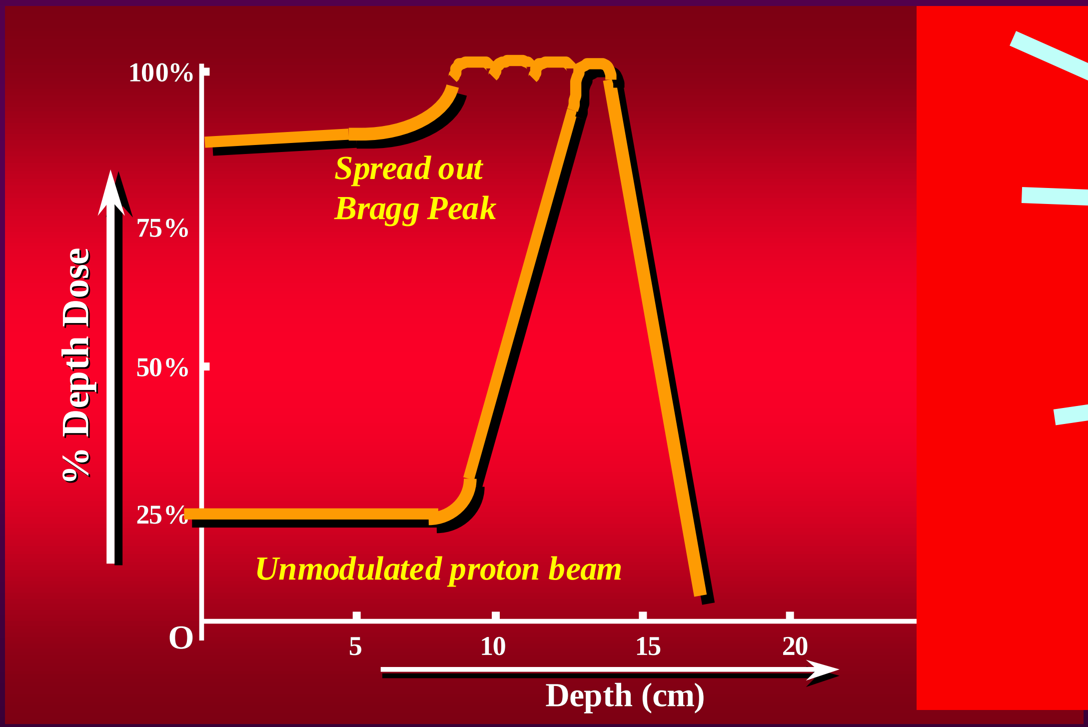
(EACH SOURCE ACTS AS A FIELD)

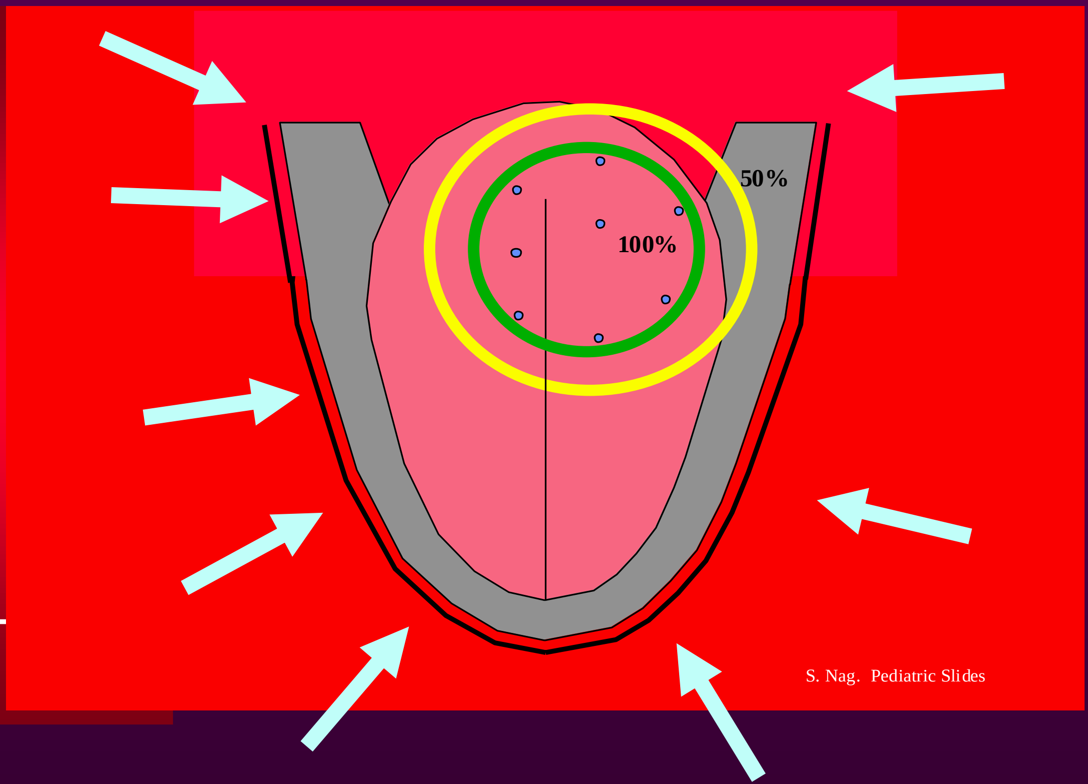


Normal tissue sparing therapy

PROTON BEAM
$80,000,000

BRACHYTHERAPY
$8,000





What is brachytherapy?
(in teletherapy language)

A super-advanced radiation modality which is:

- Intensity modulated (like IMRT),
- 3-D conformal (like CRT),
- respiratory-gated,
- organ tracking,
- multi-field,
- limited penetration (like electron beam),
- normal tissue by-passing (like proton beam)

Unfortunately it does not get the attention it deserves because it does not cost multi-million dollars

Take home message

- Brachytherapy gives high dose to tumor (better cell kill)
  - sources are within/close to tumor
  - higher dose in center
- Brachytherapy spares surrounding normal tissues (lowers morbidity)
  - sharp fall-off (inverse square law)
  - PTV closely approximates CTV (does not need margin for organ movement, patient movement, set-up errors)

Take home message

- Brachytherapy alone for small, localized tumors, or for salvage of previously irradiated tumors
- Brachytherapy more commonly used as a boost to EBRT to give higher dose with less side effects
- Treatment planning essential to ensure adequate tumor coverage without exceeding surrounding normal tissue tolerance

Take home message

Areas of continued/future development:

- Prostate brachytherapy
- HDR brachytherapy
- Computerization
- Image guidance
- Minimally invasive
- Cure with preservation of function/cosmesis/improved quality of life

Take home message

- Demonstrate efficacy in randomized, controlled, clinical trials
- Quality assurance, expertise required for successful outcome
  - fellowships, courses, workshops, textbooks
- Scope of brachytherapy limited only by:
  - skill, dexterity and innovative abilities of the brachytherapist

We still have lofty peaks to climb!