Plan Evaluation in Head & Neck Brachytherapy

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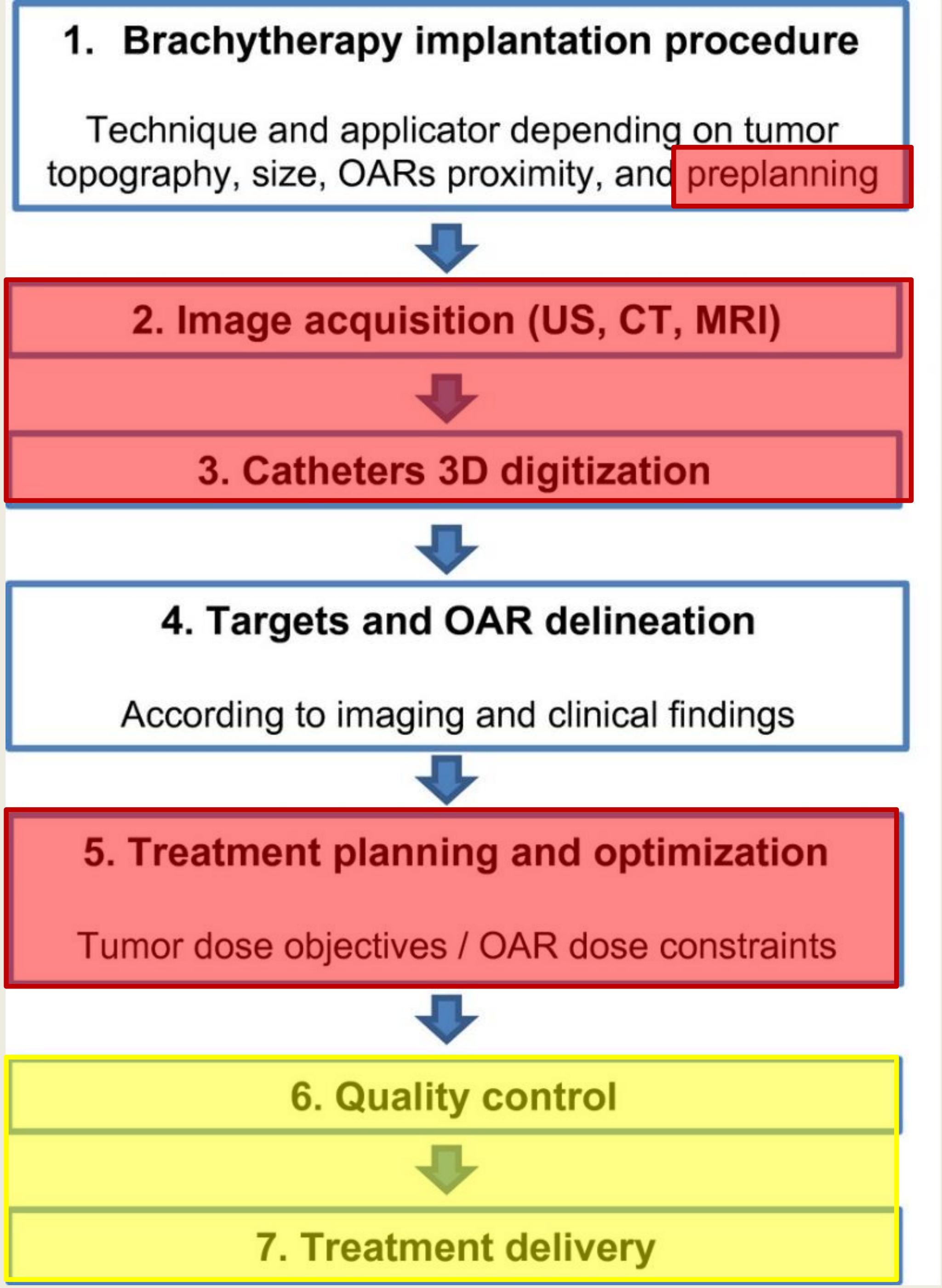


Chargari C et al, Brachytherapy: An overview for clinicians. CA: a cancer journal for clinicians. 2019 Sep;69(5):386-401.

Why & How?

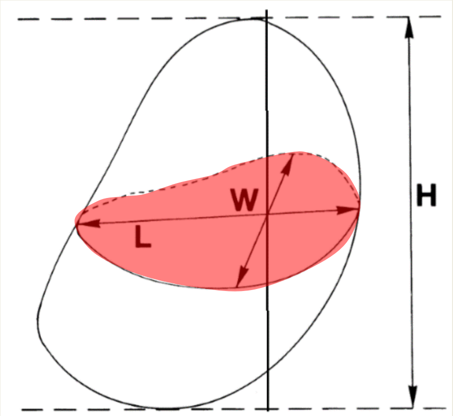
- Multidisciplinary– Physician (RO & Surg) & Physicist
- H&N- lip, tongue, floor of mouth, palate, buccal mucosa, etc.
- Tx- Interstitial or Mould
- Radiograph based planning may raise ethical issues
- CT - accurately tailors the treatment plan

Implantation Rules

- As per size – Single/double plane or volume implant
- Thickness of 10 mm– Single plane
- Thickness 10 to 25 mm – Double plane
- > 25 mm multiple planes
- Surface mould - 5mm

ICRU 58

- PTV = CTV (max. dimension in three orthogonal directions)
- Treated volume = Volume of ref isodose encompassing CTV
- Central Plane – In centre, where source are straight, parallel & perpendicular to source lines
- MCD - mean central dose is the mean of the minimum doses between sources (Basal Dose)
- MTD - minimum dose at the periphery of CTV (Ref Dose)



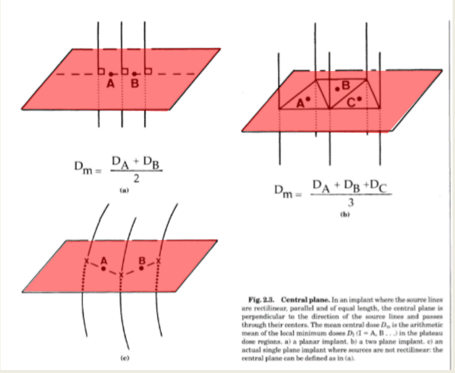
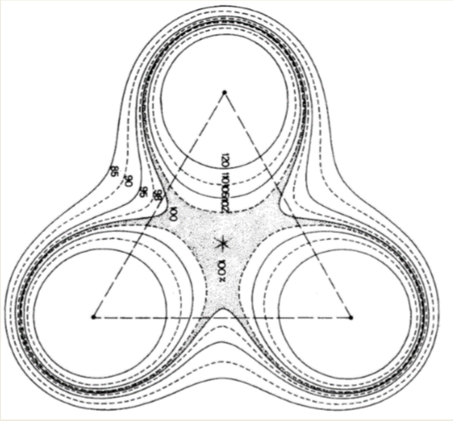


Fig. 2.3. Central plane. In an implant where the source lines are rectilinear, parallel and of equal length, the central plane is perpendicular to the direction of the source lines and passes through their centers. The mean central dose D_m is the arithmetic mean of the local minimum doses D_I (I = A, B . . .) in the plateau dose regions. a) a planar implant. b) a two plane implant. c) an actual single plane implant where sources are not rectilinear: the central plane can be defined as in (a).



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GEC-ESTRO/ACROP recommendations

GEC-ESTRO ACROP recommendations for head & neck brachytherapy in squamous cell carcinomas: 1st update – Improvement by cross sectional imaging based treatment planning and stepping source technology

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ABSTRACT

The Head and Neck Working Group of the GEC-ESTRO (Groupe Européen de Curiethérapie – European Society for Therapeutic Radiology and Oncology) published in 2009 the consensus recommendations for low-dose rate, pulsed-dose rate and high-dose rate brachytherapy in head & neck cancers. The use of brachytherapy in combination with external beam radiotherapy and/or surgery was also covered as well as the use of brachytherapy in previously irradiated patients. Given the developments in the field, these recommendations needed to be updated to reflect up-to-date knowledge.

The present update does not repeat basic knowledge which was published in the first recommendation but covers in a general part developments in (1) dose and fractionation, (2) aspects of treatment selection

GEC-ESTRO Recommendation

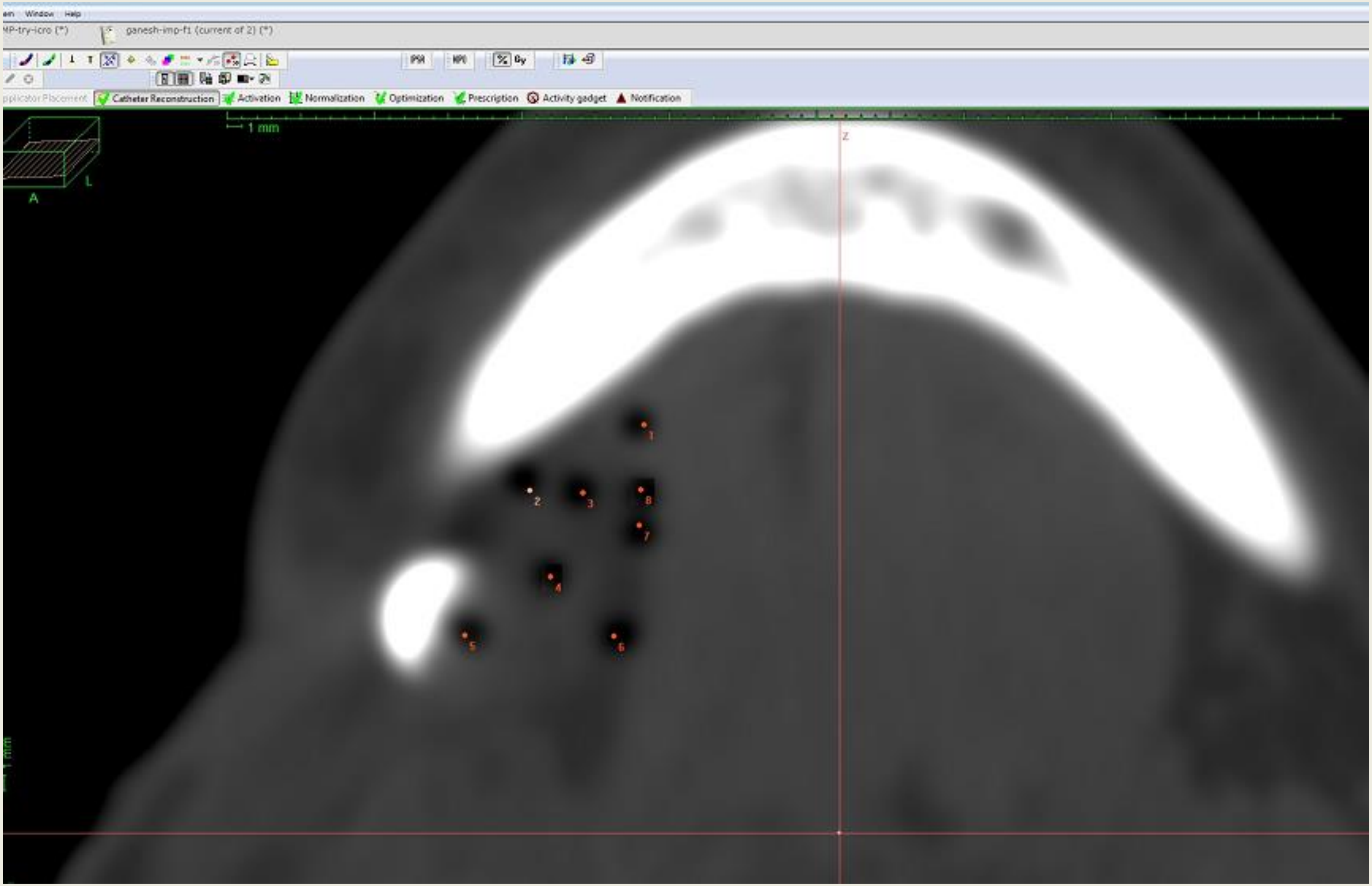
- Around CTV no additional margin
- Paris system & prior CT for no. of catheters/plane
- Adequate CTV coverage with implanted catheters
- Optimal spacing between tubes is ≤15 mm
- prescription dose is the min. dose received by the CTV or a CTV surrogate (i.e.D_{90} > 100, V_{100} > 90%).
- Hyper-dose sleeves thinnest possible
- Dose to skin, bone, nerves, vessels – Min./avoided
- Spacers between OAR and implant is encouraged

Planning Process

- Labeling - Numbering of catheters for identification
- CT based - thin slices of 1 to 2 mm
- Markers (thin Cu wires) at the edges of the tumour
- Images - free of artifacts
- Radiopaque marker or air in catheters for contrast.
- Catheter reconstruction as per labeling
- Plan evaluation - slice-by-slice visualization
- DVH

Catheter Reconstruction

Small Video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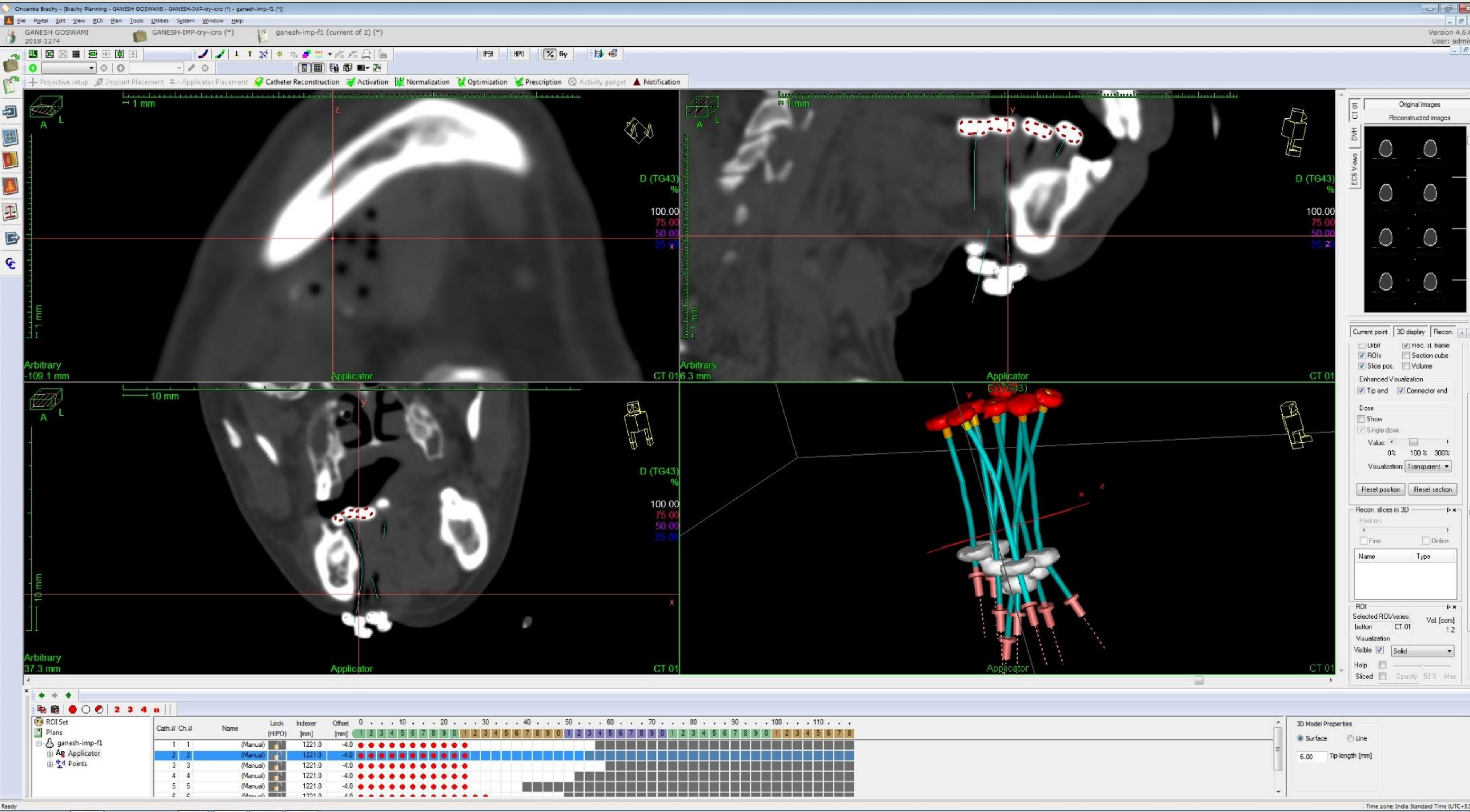

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Reconstructed images
Current point
3D display
Recon.
ROIs
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Volume
Enhanced Visualization
Tip end
Connector end
Dose
Show
Single dose
Value:
0%
100 %
300%
Visualization:
Transparent
Reset position
Reset section
Recon. slices in 3D
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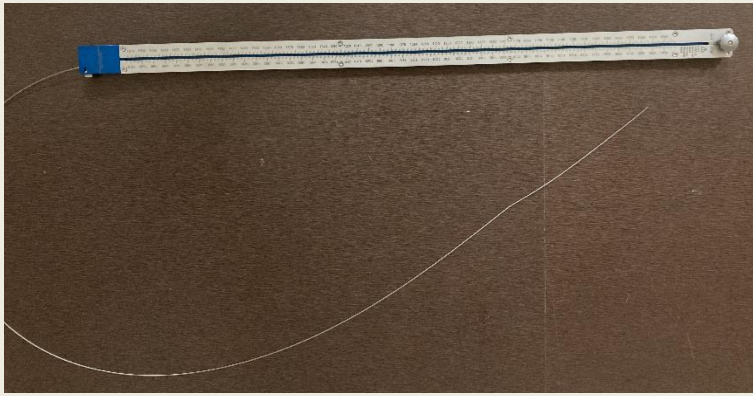
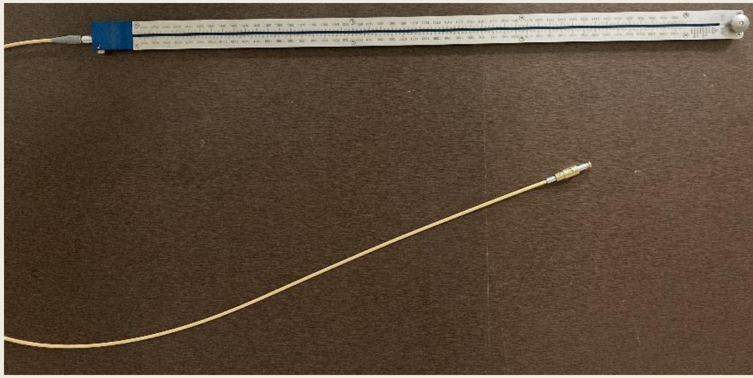
3D Model Properties
Surface
Line
6.00
Tip length [mm]
Ready
Time zone: India Standard Time (UTC+5:30)

Source Position Simulator

- Determine the length of catheter
- Clearance of the catheter paths
- kinks can be detected
- Any resistance to passage of source
  - Resistance can be anticipated during catheter reconstruction also.
- Measured length can be compared against the length of the catheter in TPS.





Planning & Dose Calculation

- Active source positions inside the PTV
- manually or automatically
- Paris system – BD in central plane is important
- BD points are placed manually or automatically
- Normalizing to mean central dose
- Dose is prescribed to the 85% of MCD
- Optimization for CTV coverage and homogeneity
- optimization is not a substitute of good implant

Optimization

- Forward optimization
- Dwell positions & dwell time manipulation manually
  - Manual dwell weights/times optimization
  - Geometrical optimization
  - Optimization on dose points
  - Graphical optimization
- Inverse optimization - optimized plan when all clinical objectives are met
  - Inverse Planning by Simulated Annealing (IPSA)
  - Hybrid Inverse Planning Optimization (HIPO)

IPSA - HIPO

IPSA

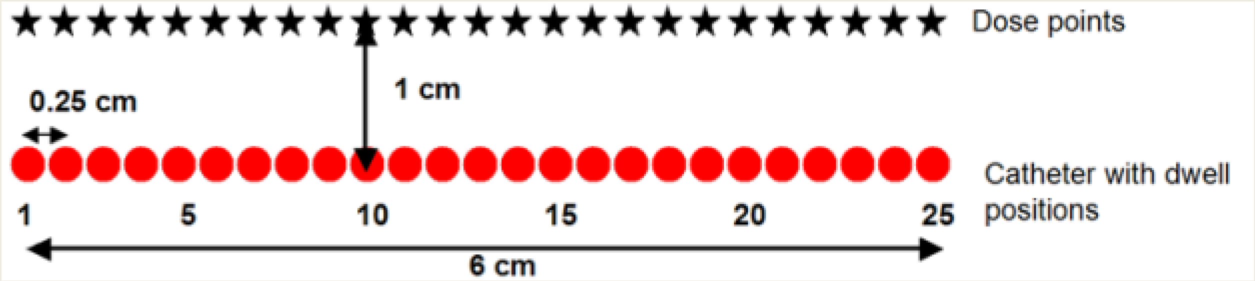
- Stochastic algorithms and slow
- Dwell times vary from 0.00 to maximum
- Produce heterogeneous dose distributions
- DTDC - large values - degradation of DVH metrics

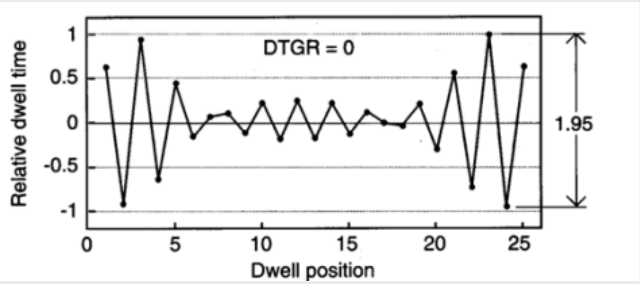
HIPO

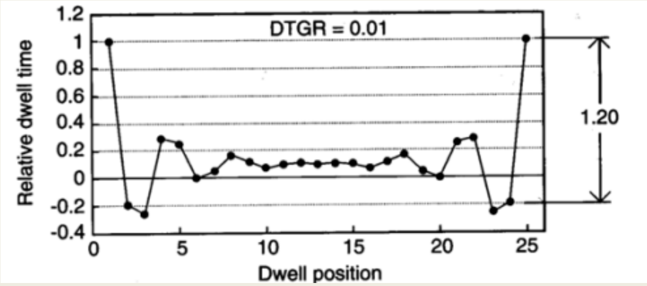
- Hybrid deterministic & stochastic dose–volume-based
- Allows to lock catheters to keep their dwell times fixed & do optimization of the remaining catheters
- Reduces selective hot spots and more uniform dwell time distribution, DTGR

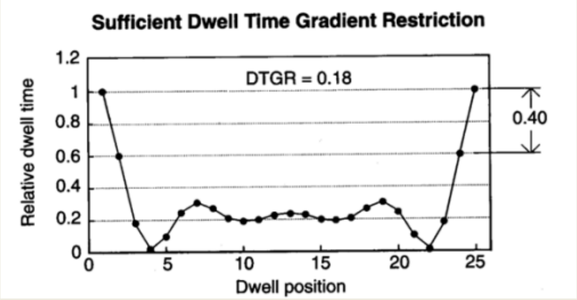
Panettieri V et al. Comparison of IPSA and HIPO inverse planning optimization algorithms for prostate HDR brachytherapy. Journal of Applied Clinical Medical Physics. 2014 Nov;15(6):256-66.

Dwell Time Gradient Restriction







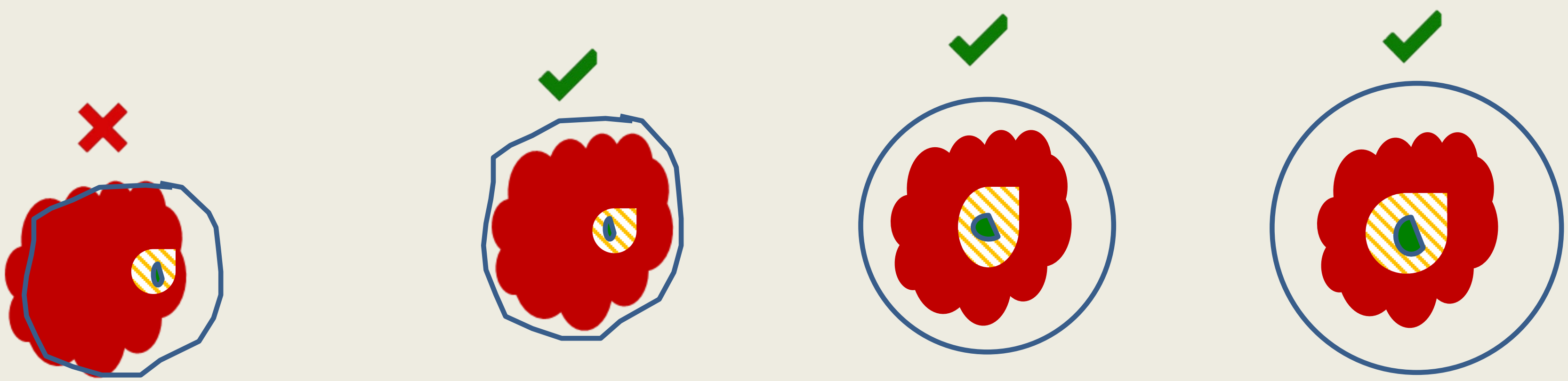


Plan Evaluation

- Classical BT – Limited PE , 2D, related to catheters/applicators, reference points
- These methods are still used
- Additional tools are now available
- Visual inspection is still relevant but subjective
  - Hot or cold spot with in the CTV
- Objective assessment with quantitative parameters is required.

Coverage Index

- Fraction of CTV receiving dose ≥ reference dose.
  - Estimate of CTV getting 100% dose
- $CI = CTV_{reference}/V_{CTV}$
- Ideal value of CI = 1 (should be ≥ 0.9)
  - $CTV_{reference}$ (cc) = 10, 12, and V_{CTV} (CC) = 12



10/12 = 0.83

12/12 =1

12/12 =1

12/12 =1

Int. J. Radiation Oncology Biol. Phys., Vol. 40, No. 2, pp. 515–524, 1998

0360-3016/98 $19.00 + .00

ELSEVIER

PII S0360-3016(97)00732-3

● *Physics Contribution*

A CONFORMAL INDEX (COIN) TO EVALUATE IMPLANT QUALITY AND DOSE SPECIFICATION IN BRACHYTHERAPY

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Steps in planning process to determine COIN

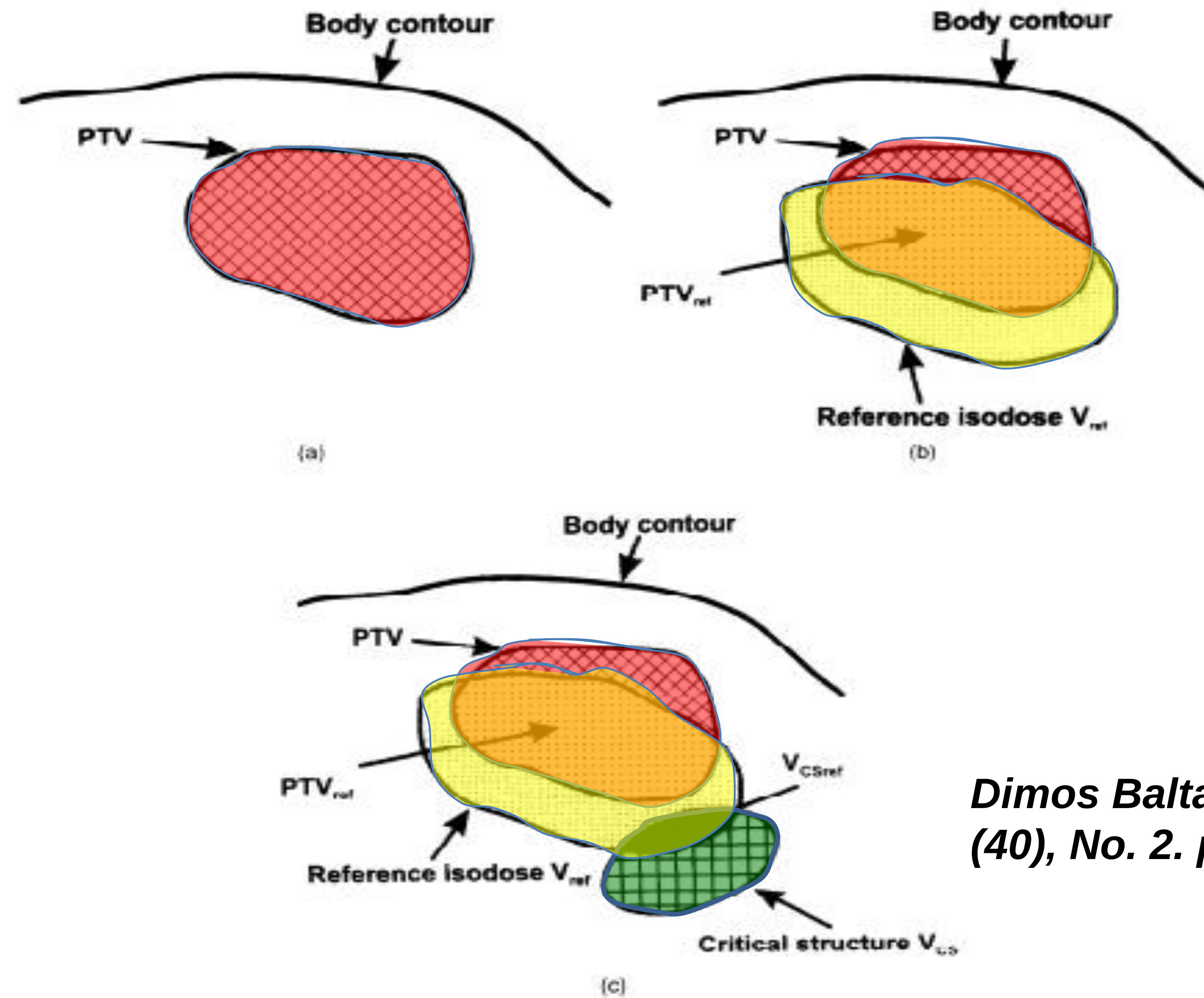
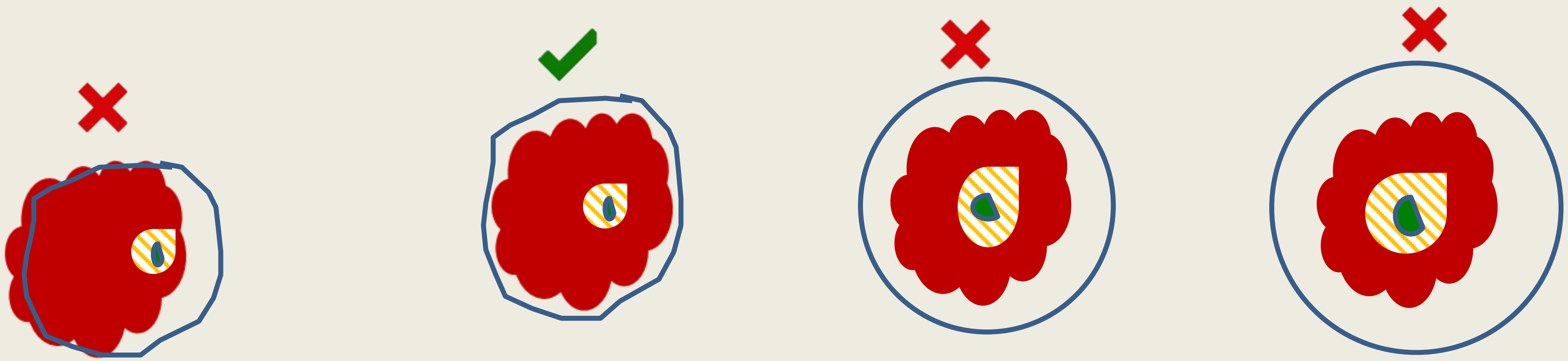


Fig. 1. Schematic diagrams of volumes necessary for computation of the conformal index COIN. (a), (b) and (c) follow the chronological order in which the volumes have to be defined.

Dimos Baltas, et al, IJROBP (40), No. 2. pp. 515-524, 1998

Conformity Index (COIN)

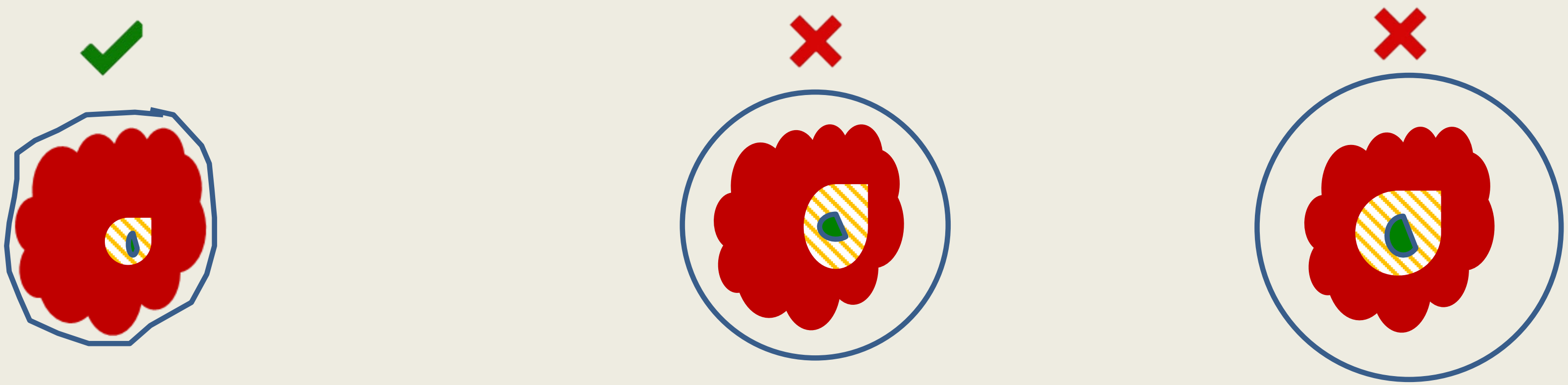
- How well the reference dose encompasses the CTV and excludes healthy tissue
  - Quantitative evaluation of conformity *(Baltas D et al 1998)*
  - COIN does not depend on a definition of homogeneity
- $COIN = CI \times CTV_{reference} / V_{reference}$
- Ideal value = 1.
  - $CTV_{reference}$ (cc) = 10, 12, and V_{ref} (CC) = 14, 15, 20



0.83*10/14 = 0.60 | 1*12/14=0.86 | 1*12/15=0.8 | 1* 12/20=0.60

External Volume Index (EI)

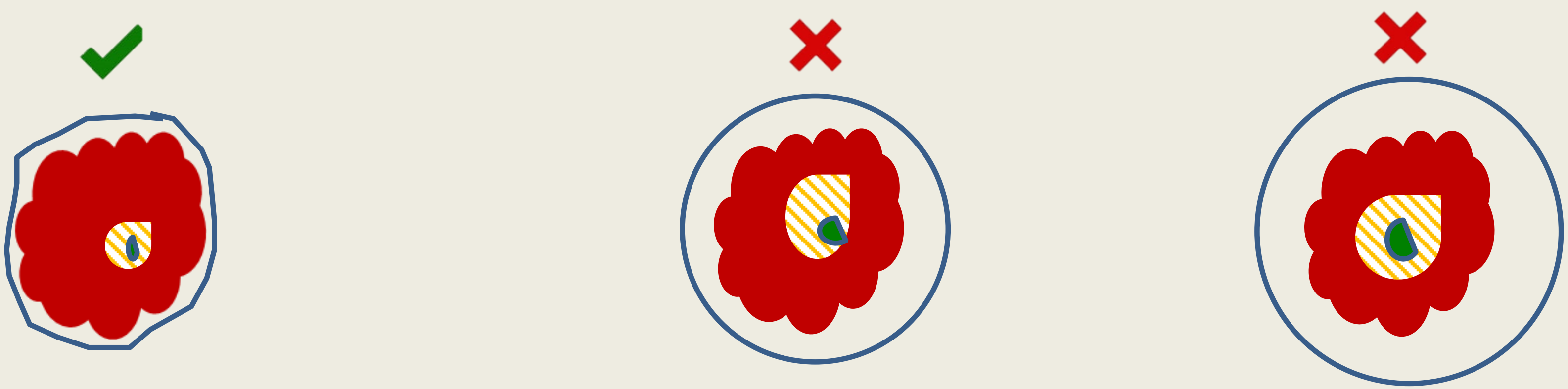
- Indicator of dose gradient beyond CTV
- Ratio of normal tissue volume outside CTV (receiving ≥ ref dose) to Volume of CTV
- Ideal value of EI = 0.0
- $EI = \frac{NTV_{ref}}{V_{CTV}}$ ($NTV_{ref} = V_{ref} - CTV_{ref}$)



$\frac{14-12}{12} = 0.17$ $\frac{15-12}{12} = 0.25$ $\frac{20-12}{12} = 0.67$

Dose Homogeneity Index

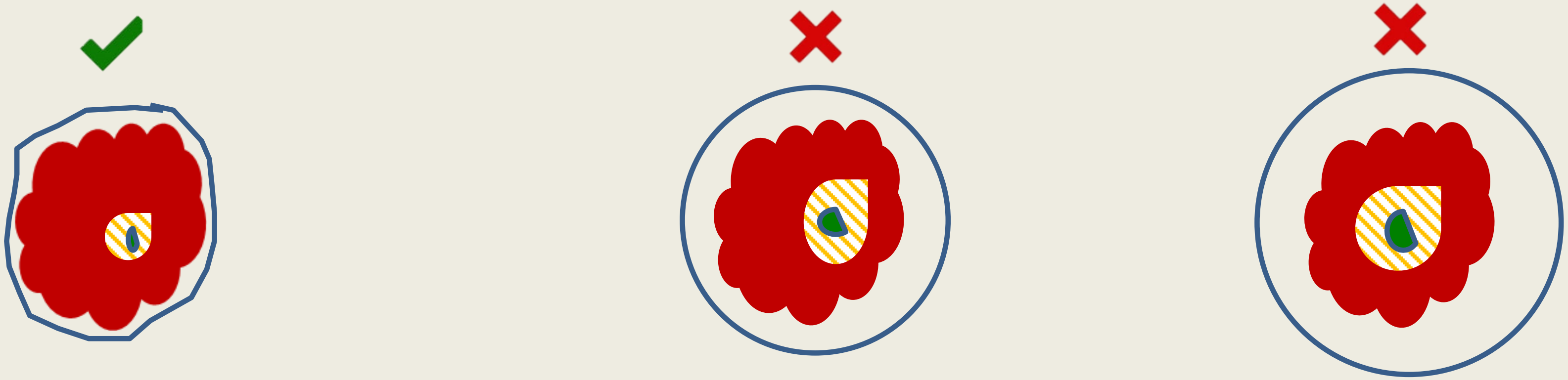
- Dose inhomogeneity is a reality & can't be removed
- The ratio of CTV receiving 1-1.5 times of ref. dose to the CTV receiving ref dose.
- Ideal value = 1
- $$DHI = \frac{CTVD_{reference} - CTV1.5D_{reference}}{CTVD_{reference}}$$



(12-5)/12 = 0.58   (12-6)/12 = 0.5   (12-8)/12 =0.3

Overdose Volume Index (ODI)

- Ratio of CTV (receiving ≥ 2 times of ref dose) to the CTV receiving ≥ ref dose
- Indicator of dose gradient beyond CTV
- Ideal value of ODI = 0.0
- ODI= $CTV2D_{ref}/CTVD_{ref}$

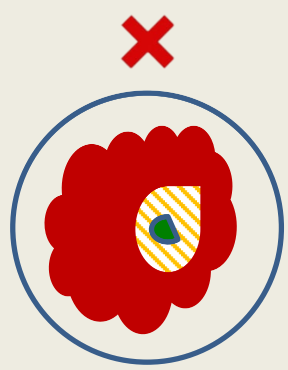


3/12 = 0.25 4/12 = 0.33 5/12 =0.42

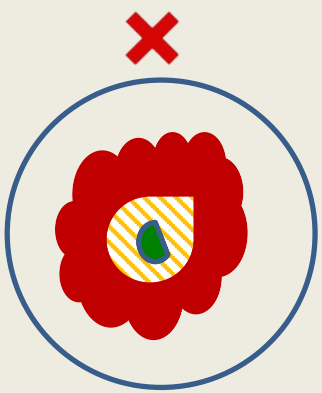
Dose Nonuniformity Ratio

- Ratio of the CTV receiving ref dose to CTV getting 1.5 times of reference dose
- $DNR=CTV1.5D_{reference}/CTVD_{reference}$
- Ideal DNR = 0

5/12 = 0.42



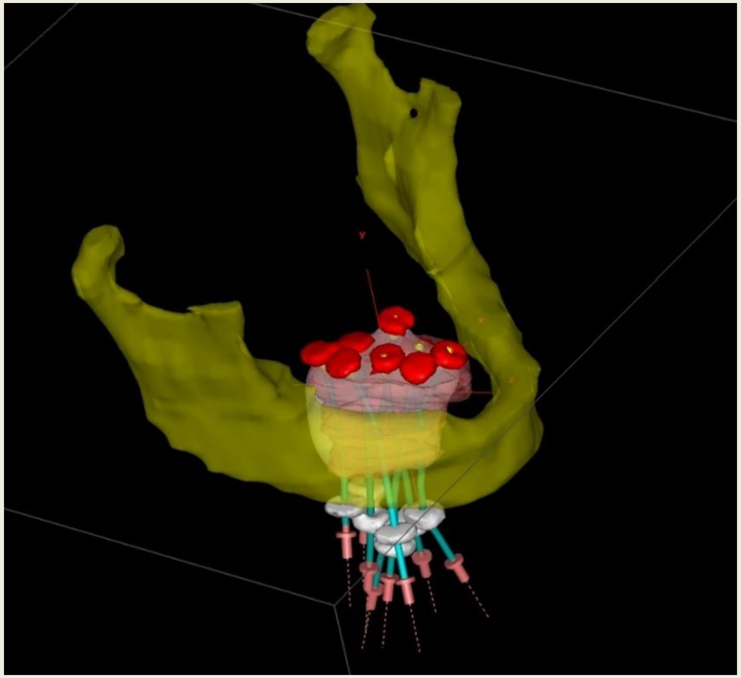
6/12 = 0.50



8/12 =0.67

Analysis

Volumes (CC)	Plan-1	Plan-2	Plan-3	Plan-4
CTV_{ref}	10	12	12	12
V_{CTV}	12	12	12	12
V_{ref}	14	14	15	20
NTV_{ref}	4	2	3	8
$CTV_{1.5Dref}$	5	5	6	8
CTV_{2Dref}	3	3	4	5
CI	0.83	1	1	1
COIN	0.6	0.86	0.80	0.6
ODI	0.3	0.25	0.33	0.42
DHI	0.5	0.58?	0.5	0.3
EI	0.33	0.17	0.25	0.67
DNR	0.5	0.42	0.5	0.67



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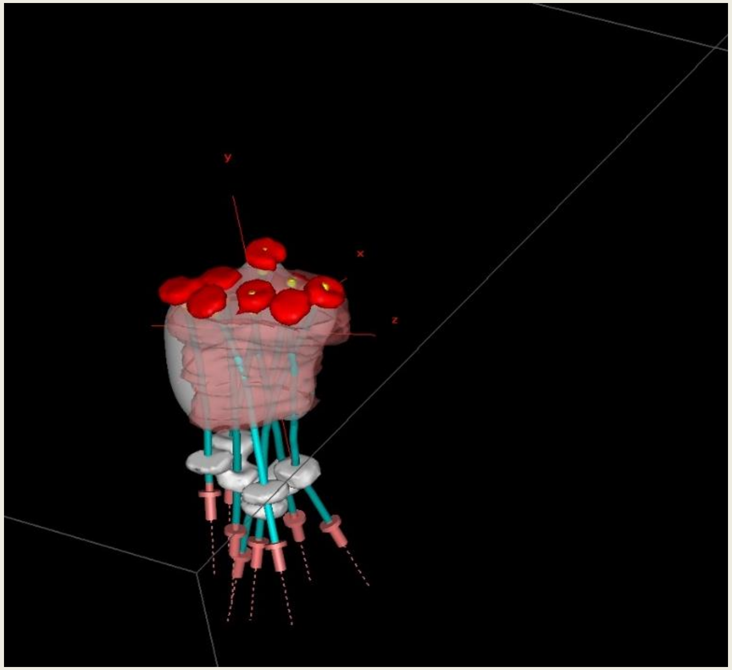


y
x
z

	INPUT (cc)	INPUT (%)		OUTPUT	acceptance level
CTV_{100}	9.52		***Coverage Index (CI)***	0.95	
CTV_{150}	3.79		***Conformity Index (COIN)***	0.60	Yes
CTV_{200}	1.88		***Dose Homogeneity Index (DHI)***	0.60	
CTV_{300}	0.00		***Plan Quality Index (PQI)***	2.15	Good
V_{CTV}	10.07		***Dose Non-uniformity Ratio (DNR)***	0.40	**YES**
IV_{100}	14.95		***Over Dose Volume Index (ODI)***	0.20	
NTV_{100}	5.43		***External Volume Index (EI)***	0.54	

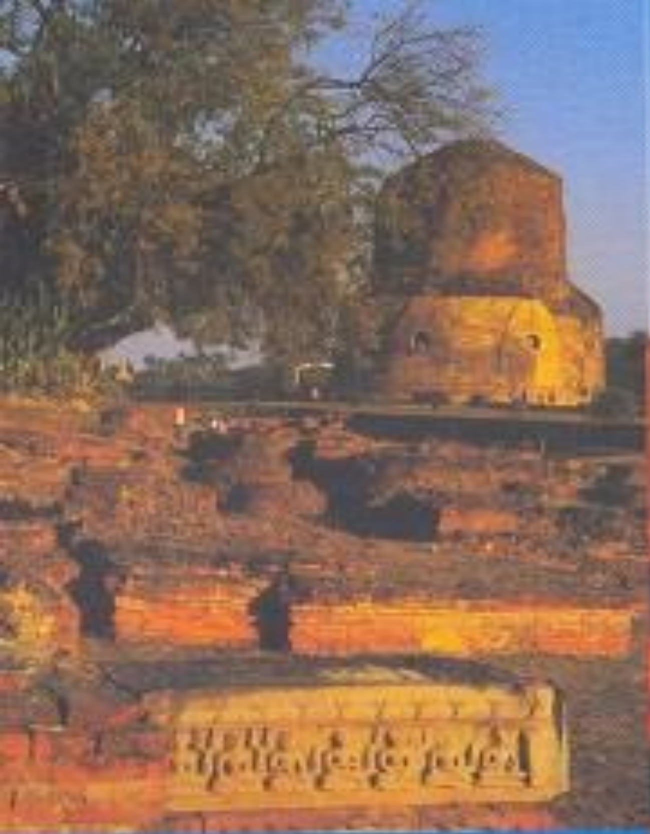
Abbreviations
CTV_{100} volume of CTV receiving 100% of prescription dose
CTV_{150} is the volume of CTV receiving 150% of prescription dose
CTV_{200} is the volume of CTV receiving 200% of prescription dose
CTV_{300} is the volume of CTV receiving 300% of prescription dose
VCTV is the volume of CTV
IV_{100} is the volume covered by 100% of isodose surface
NTV_{100} is the volume of normal tissue (excluding target) receiving 100% dose

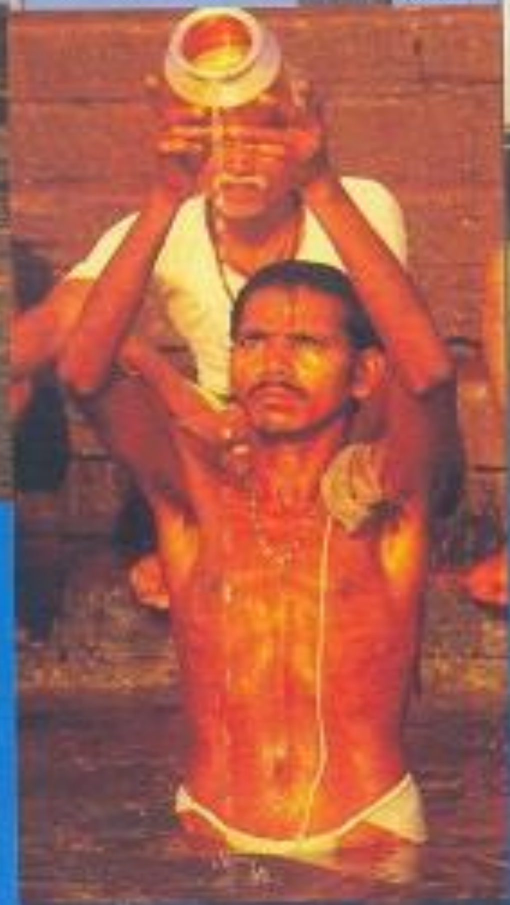
PQI = CI + COIN + DHI

Useful for comparing plans using different optimization method for same case, if its 3,consider as ideal plan

Conclusion

- Plan evaluation is tricky
- Quantitative outcome depends upon contouring
- Plan indices help in choosing good plan
- Good research tool
- Correlation between indices and clinical outcome is useful





Thank you