Physics of Breast Brachytherapy

Conventional
to
Conformal
Brachytherapy treatment planning

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Implant Dosimetry

Conventional treatment planning

- Using set of radiograph (orthogonal or variable angle)
- Practiced since the inception of BT
- Lack of dosimetric information on patient anatomy

Conformal treatment planning (2005 in TMH)

- Using CT/MR images & advanced software algorithms
- More precise, becoming popular now
- Provide clinically realistic information

Radiograph based planning

- Localization
- Treatment Planning
- Plan Evaluation

Radiograph based planning

Localization:

Done on simulator or X-ray Machine

- Patient positioning
- Identification of implant tubes
- Insertion of X-ray markers (dummies)
- Acquisition of set of radiographs
- Measurement of tube length

Radiograph based planning (Localization)

Patient positioning:

- Supine, Arm above the head
- Try to orient patient in such a way that implant plane becomes nearly perpendicular to beam axis
- To make implant tubes more distinguishable on radiographs

Radiograph based planning (Localization)

Identification of implant tubes:

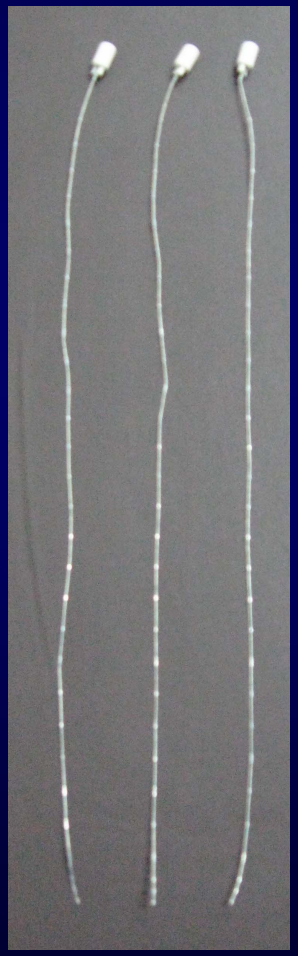
- Identification of implant planes
- Numbering of catheters in each plane
- Immobilization of tubes from open end (flags)

Radiograph based planning (Localization)

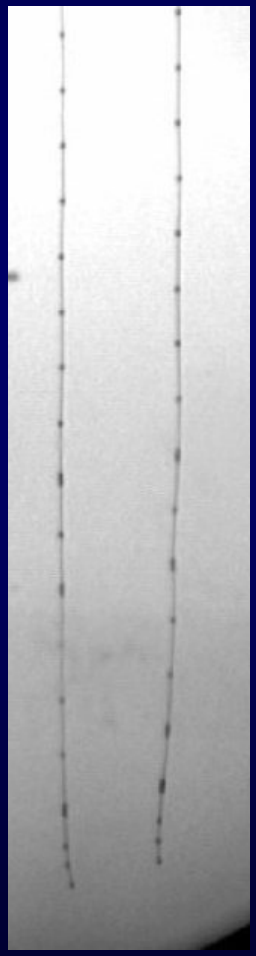
Insertion of X-ray markers (Dummies):

- Dummies provided by manufacturer
- Binary coded numbering
- Dummy should reach to the tip end of the implant tube

Dummy

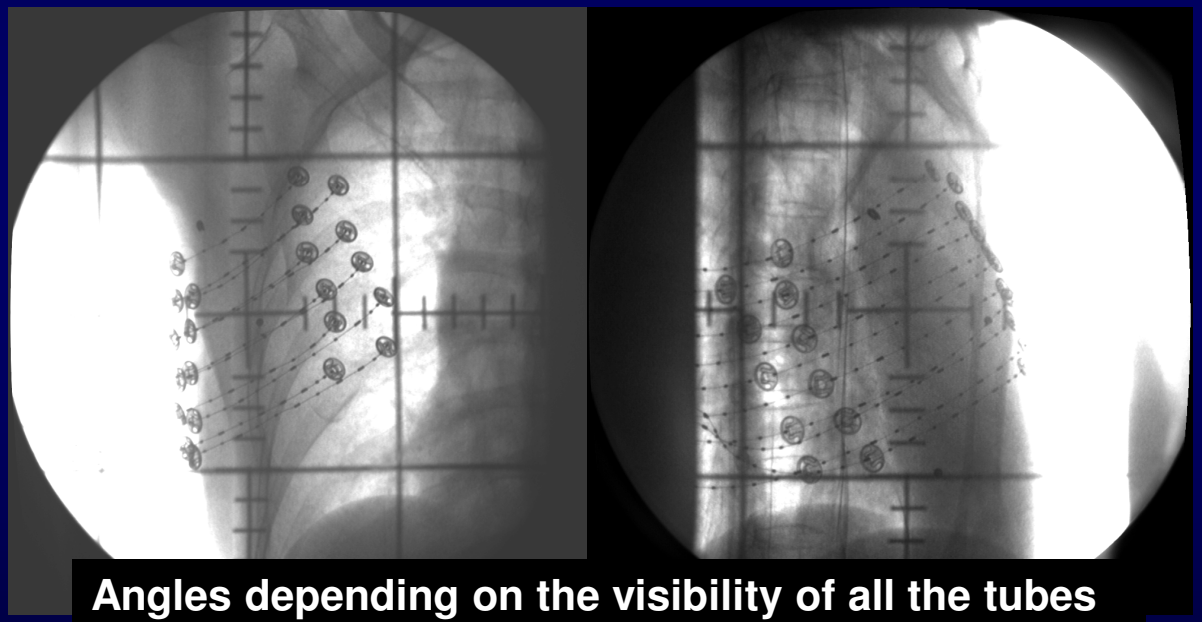


Radiograph

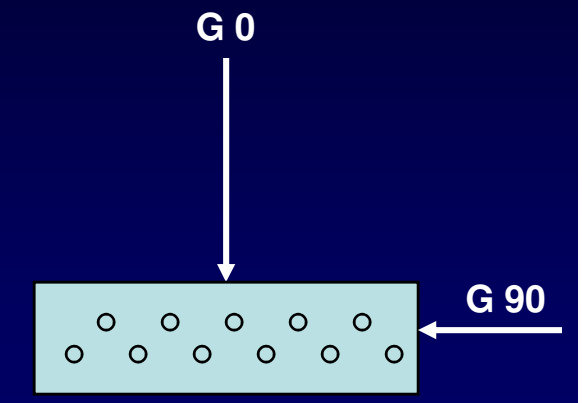


Radiograph based planning (Localization)

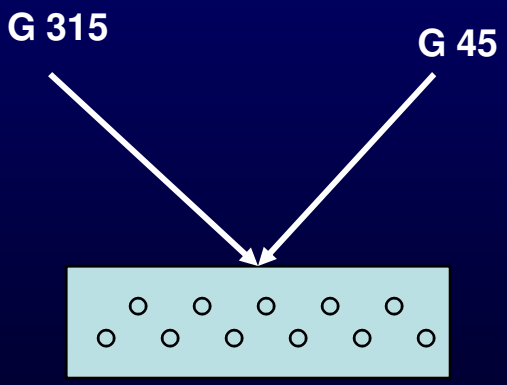
Acquisition of radiographs:



Angles depending on the visibility of all the tubes



Orthogonal



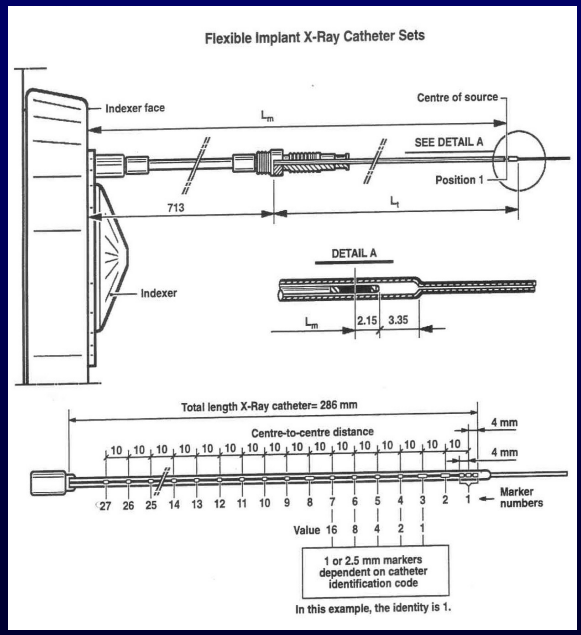
Variable angle

Radiograph based planning (Localization)

Measurement of tube length:

To determine Indexer Length:

"The distance travel by source to reach first dwell position from a reference point in machine"



Radiograph based planning

- Localization
- Treatment Planning
- Plan Evaluation

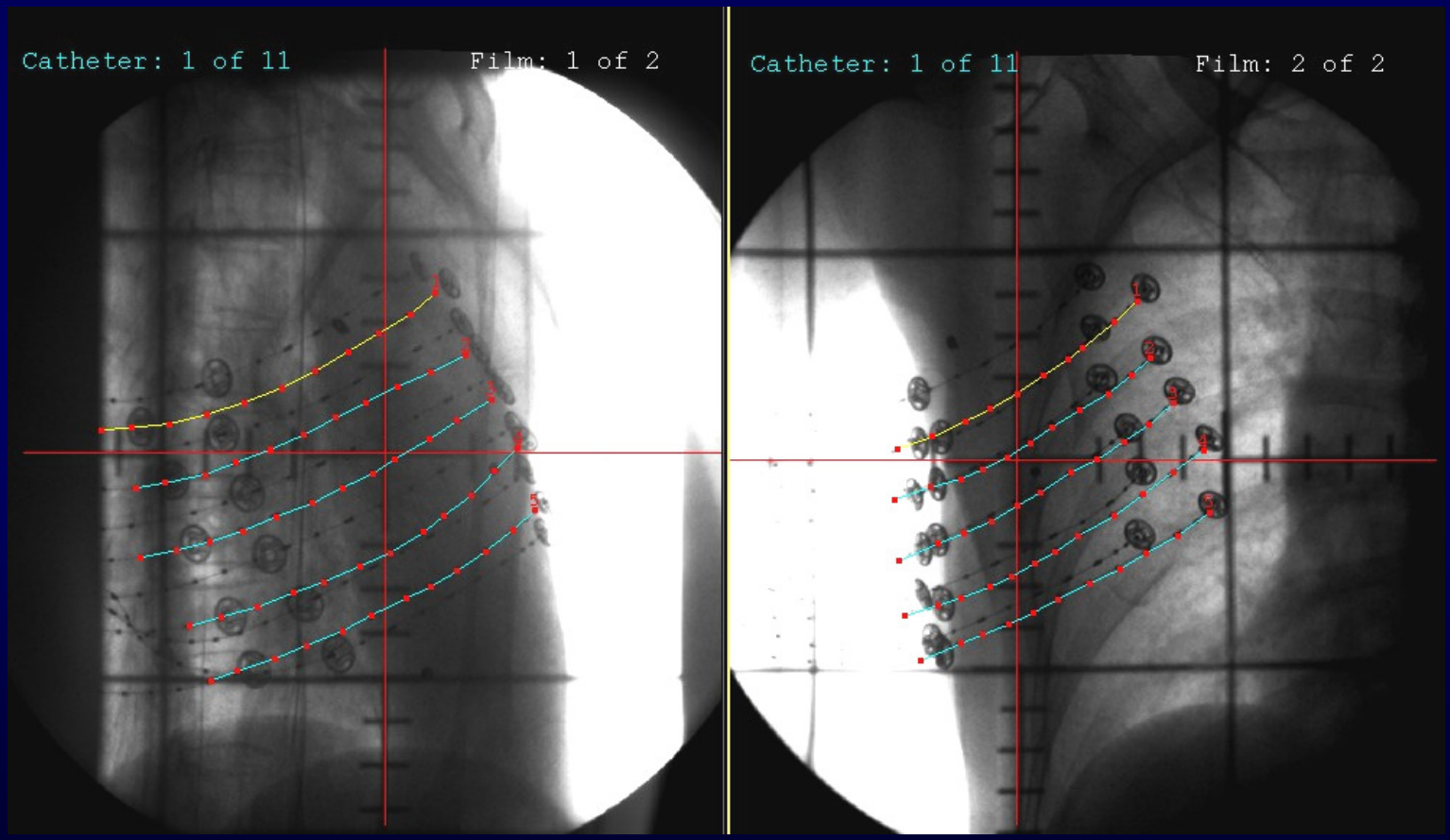
Radiograph based planning

Treatment Planning:

- Reconstruction of implant tubes
- Determination of source loading
- Determination of Basal Dose points
- Dose prescription
- Optimization

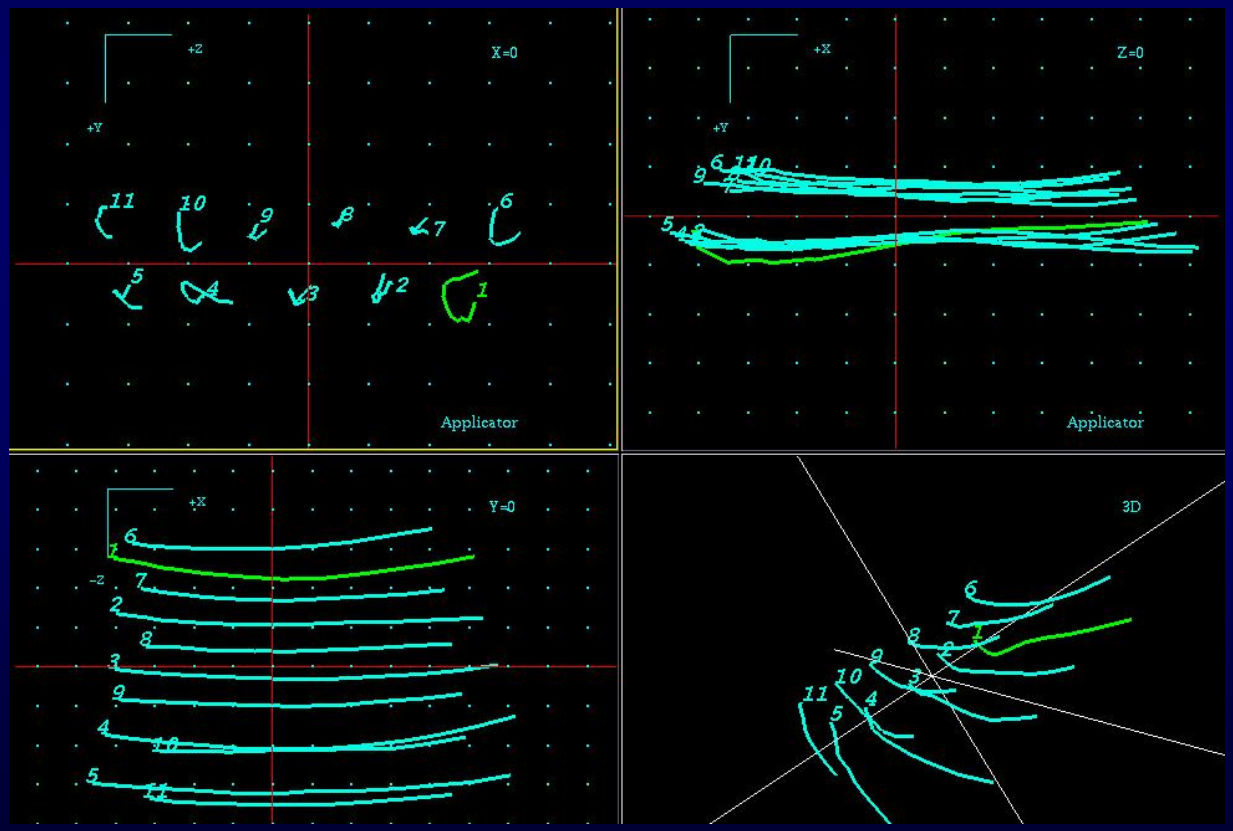
Radiograph based planning (Treatment Planning)

Reconstruction of implant tubes:



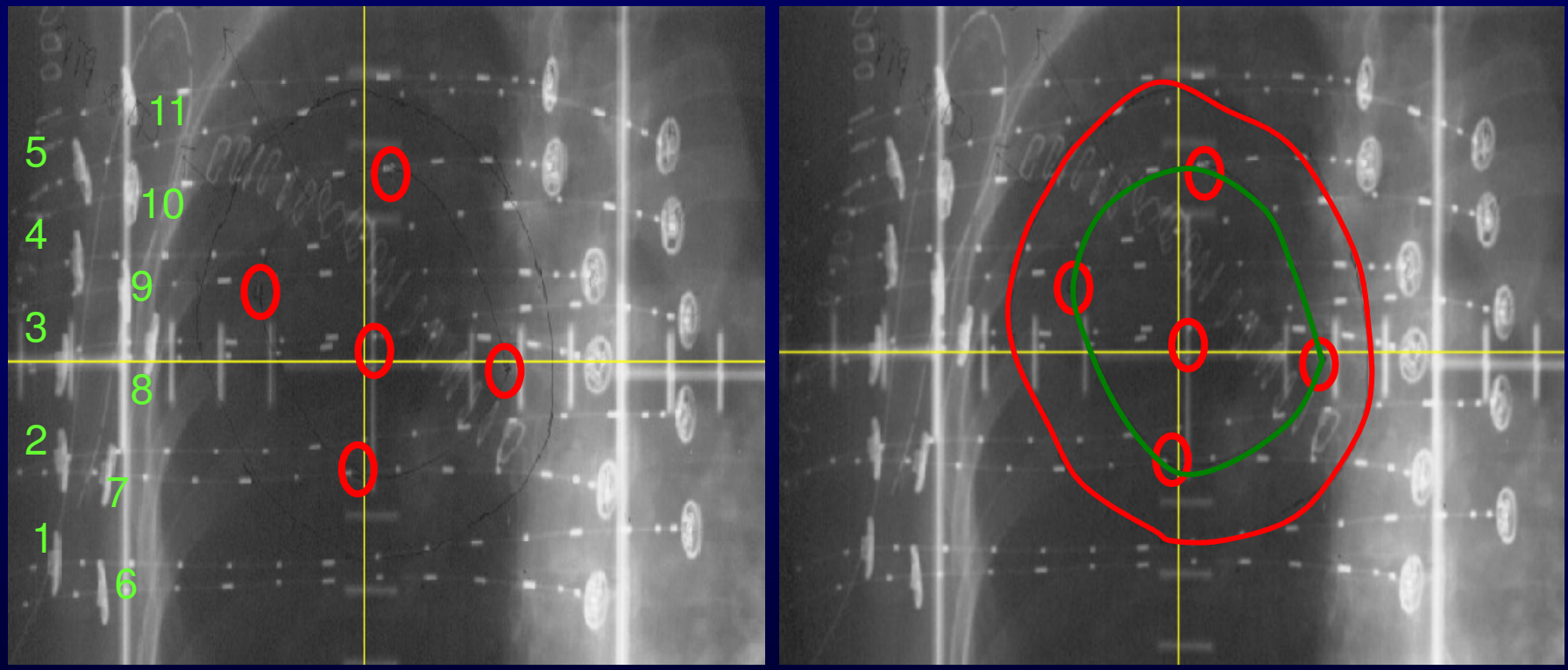
Radiograph based planning (Treatment Planning)

Reconstructed images



Radiograph based planning (Treatment Planning)

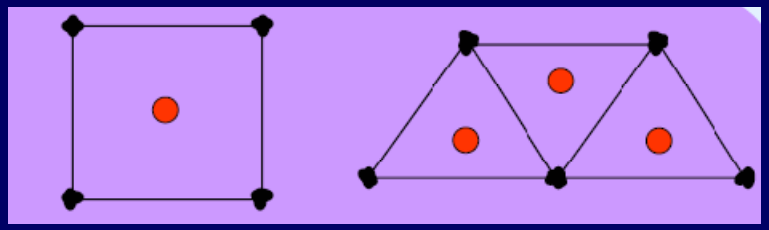
Determination of source loadings



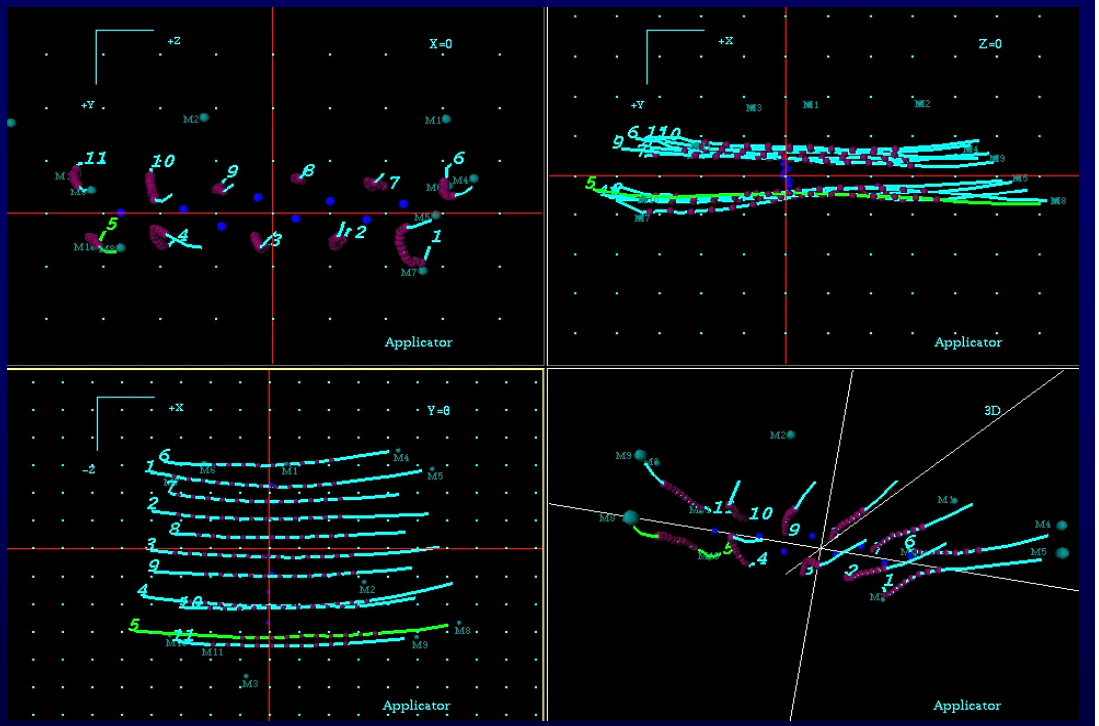
Radiograph based planning (Treatment Planning)

Determination of Basel Dose points

Points at local dose minima



At geometric centre of triangle or square formed by neighboring tubes at the mid of transverse plane of implant



Radiograph based planning (Treatment Planning)

Dose prescription:

340 cGy / fraction at 85% of Basel dose

Total dose = 34 Gy in 10 fractions, 2 fraction daily

Radiograph based planning (Treatment Planning)

Optimization:

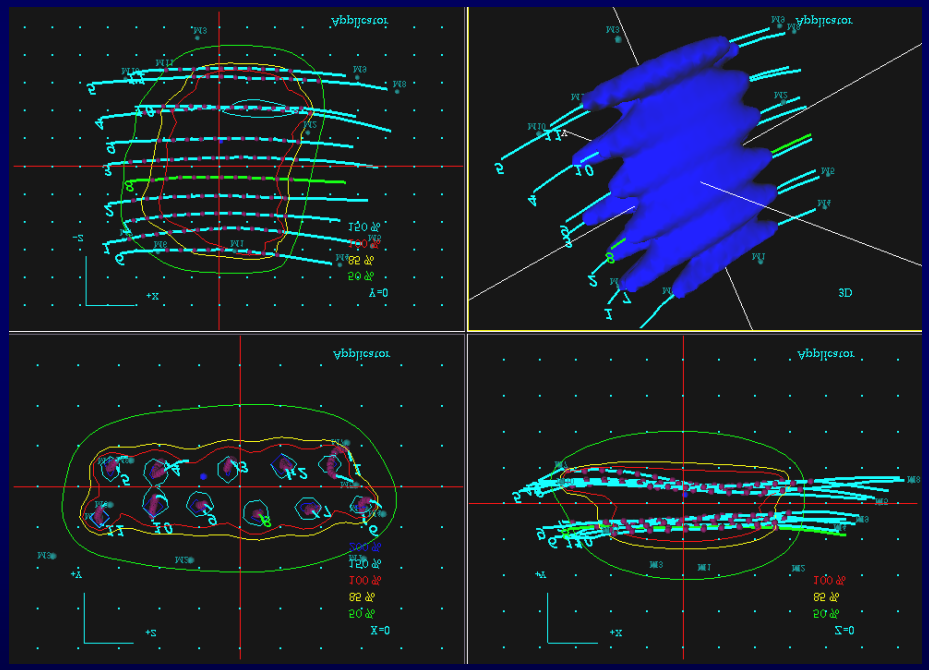
Geometrical optimization (GO) on volume

All active dwell positions are considers as dose points

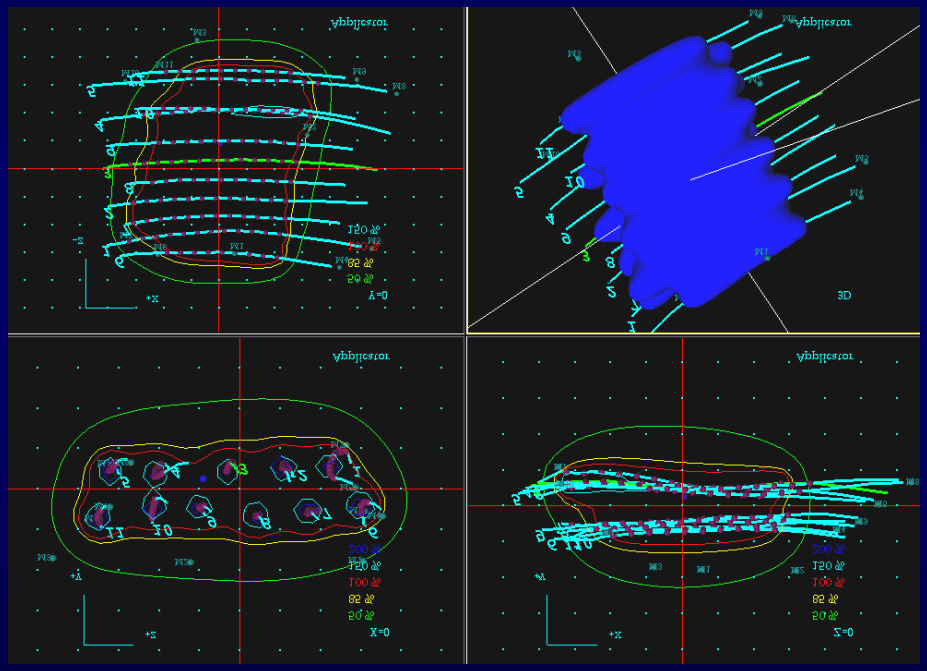
GO adjust the dwell time of stepping source in each dwell position to increases homogeneity and isodose coverage

Radiograph based planning (Treatment Planning)

Un optimize distribution



Geometrical optimization on volume



Radiograph based planning

- Localization
- Treatment Planning
- Plan Evaluation

Radiograph based planning

Plan Evaluation:

Using Cumulative DVH of Implant

Dose Homogeneity Index

DHI = $(V_{100\%} - V_{150\%})/ V_{100\%}$

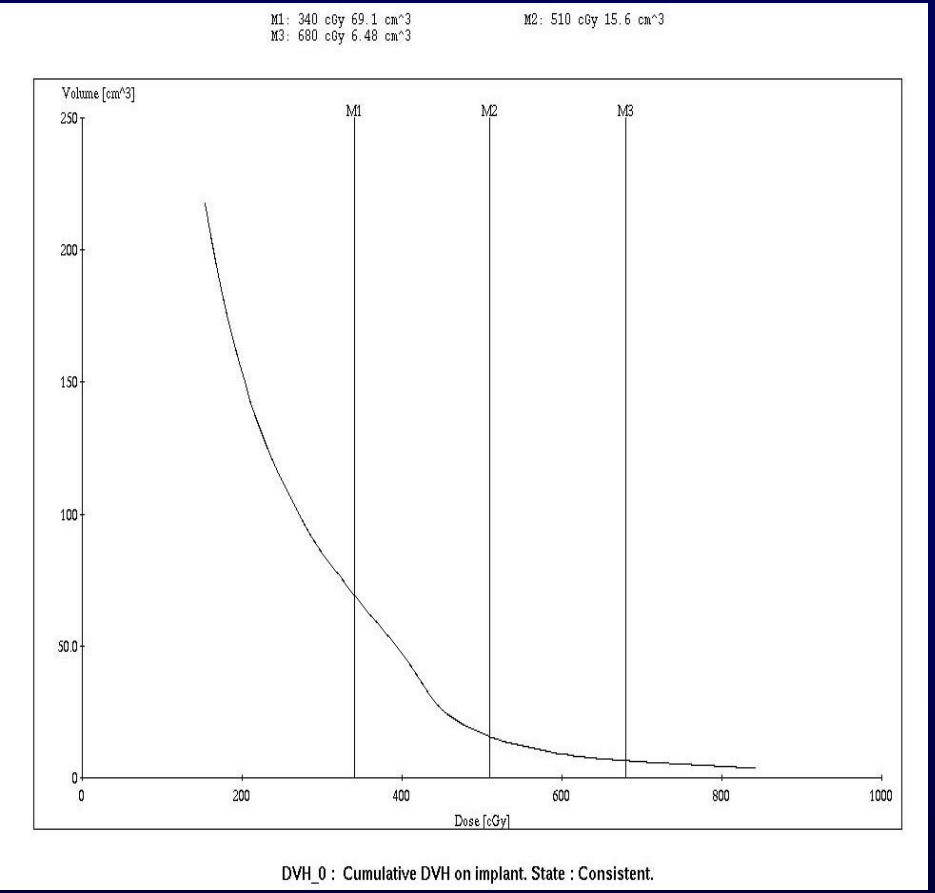
DHI > 0.75

$V_{150\%} < 70$ cc

$V_{200\%} < 20$cc

Dose to marker points

(markers at Cavity and Skin)



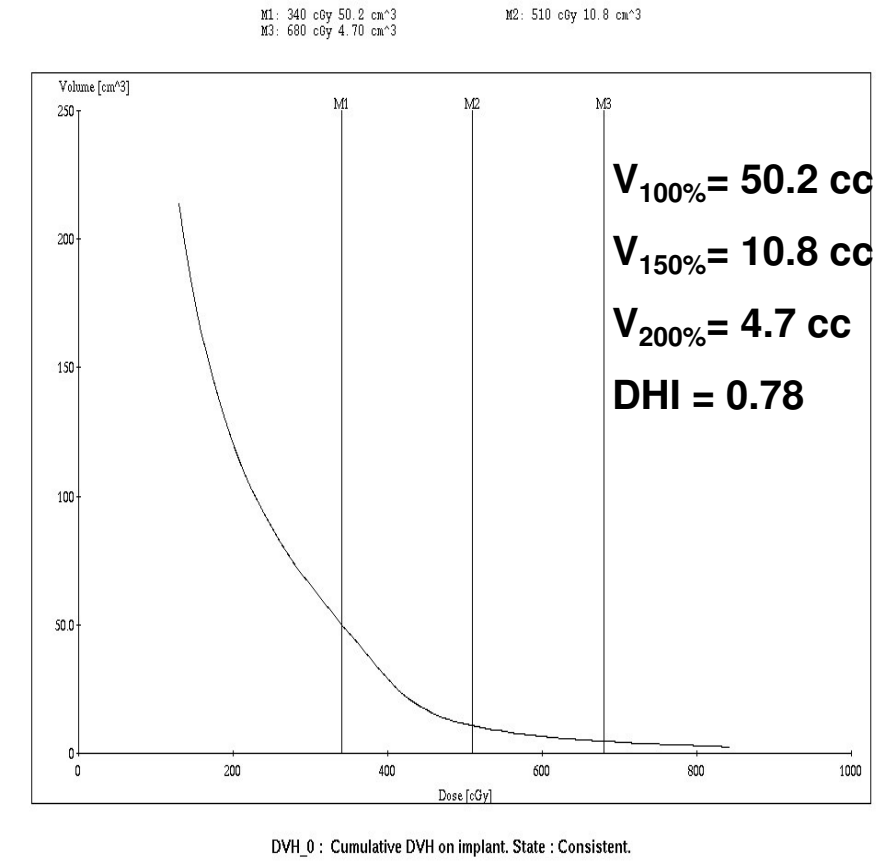
DVH_0 : Cumulative DVH on implant. State : Consistent.

RTOG 0413

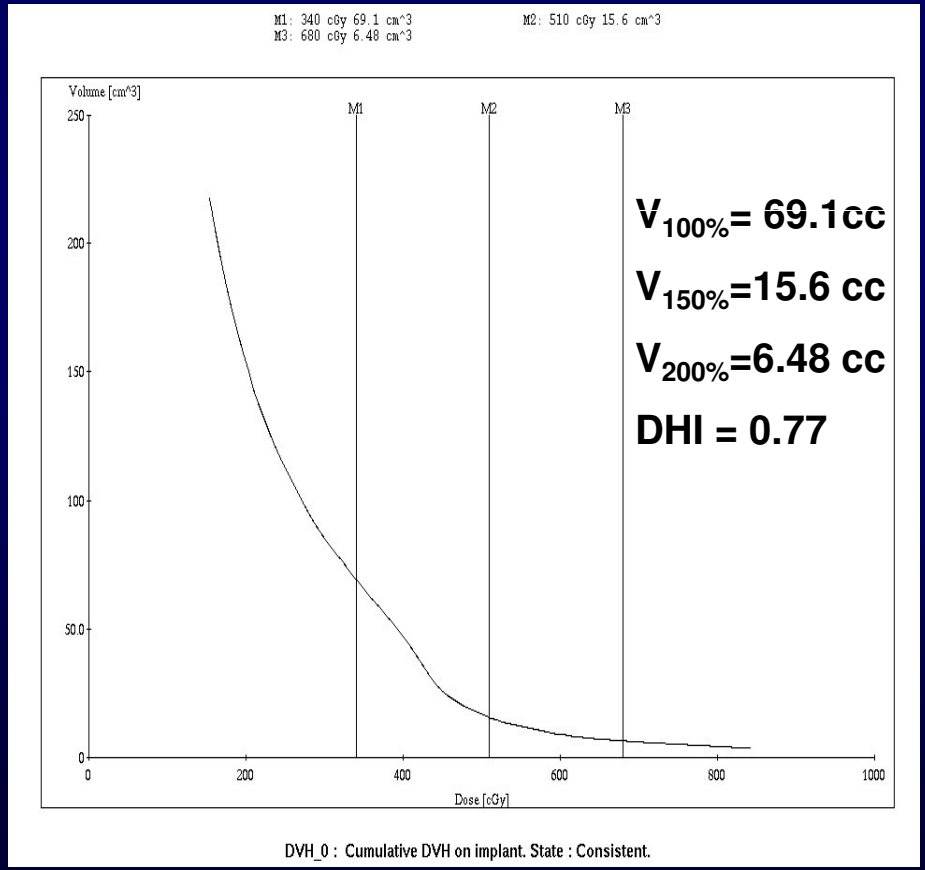
Radiograph based planning

Plan Evaluation

Un optimize Plan



Geometrically Optimize Plan



CT based 3D brachytherapy planning

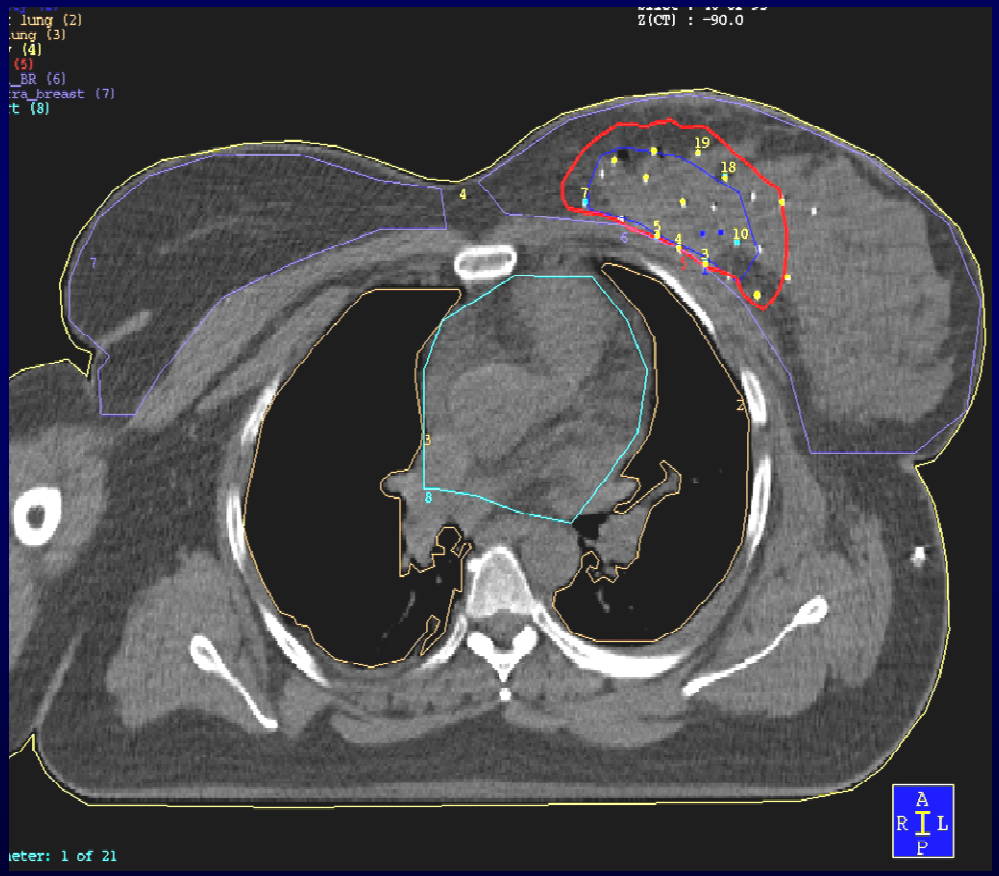
CT image acquisition

- Patient position: supine
  Both arms above the head.
- Thin copper wires (0.2mm) inserted inside the tubes for delineation
- 3 mm CT cuts from the level of mandible to several centimeters below the inframammary fold
- Entire body contour should be taken in the field of view

3D brachytherapy planning

Contouring

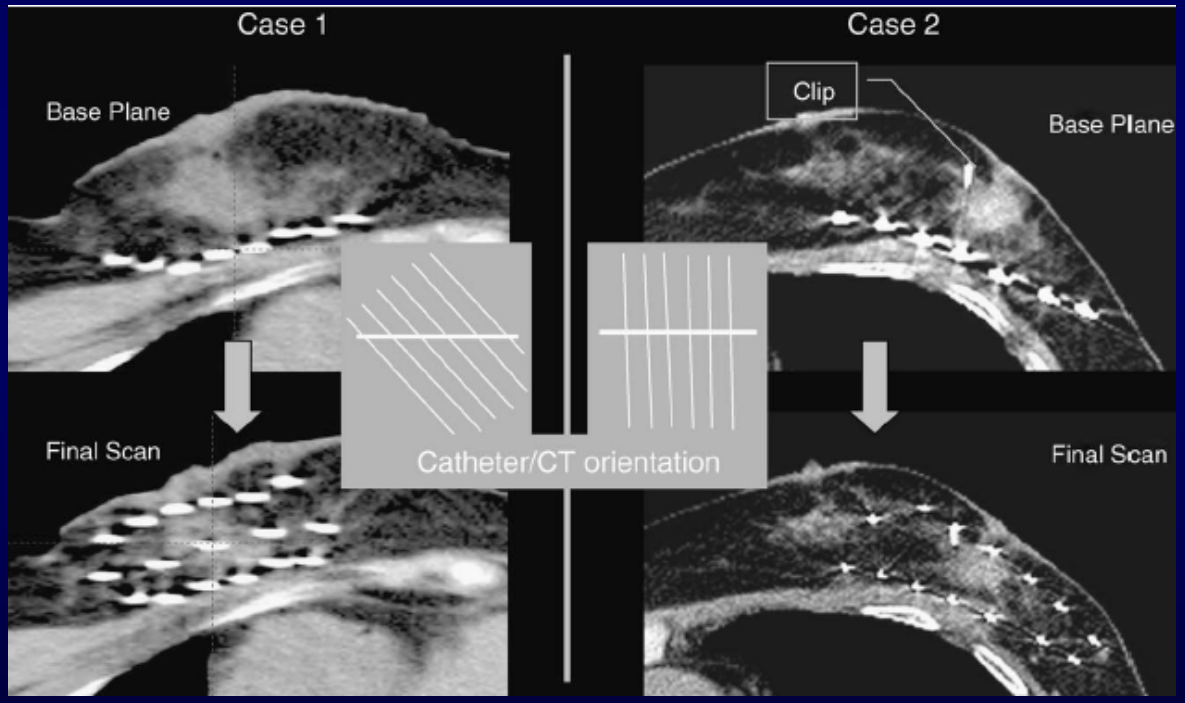
- Lumpectomy cavity
- Target (CTV)
- For brachytherapy
  PTV = CTV
- Normal breast
- Heart
- Lung



3D brachytherapy planning

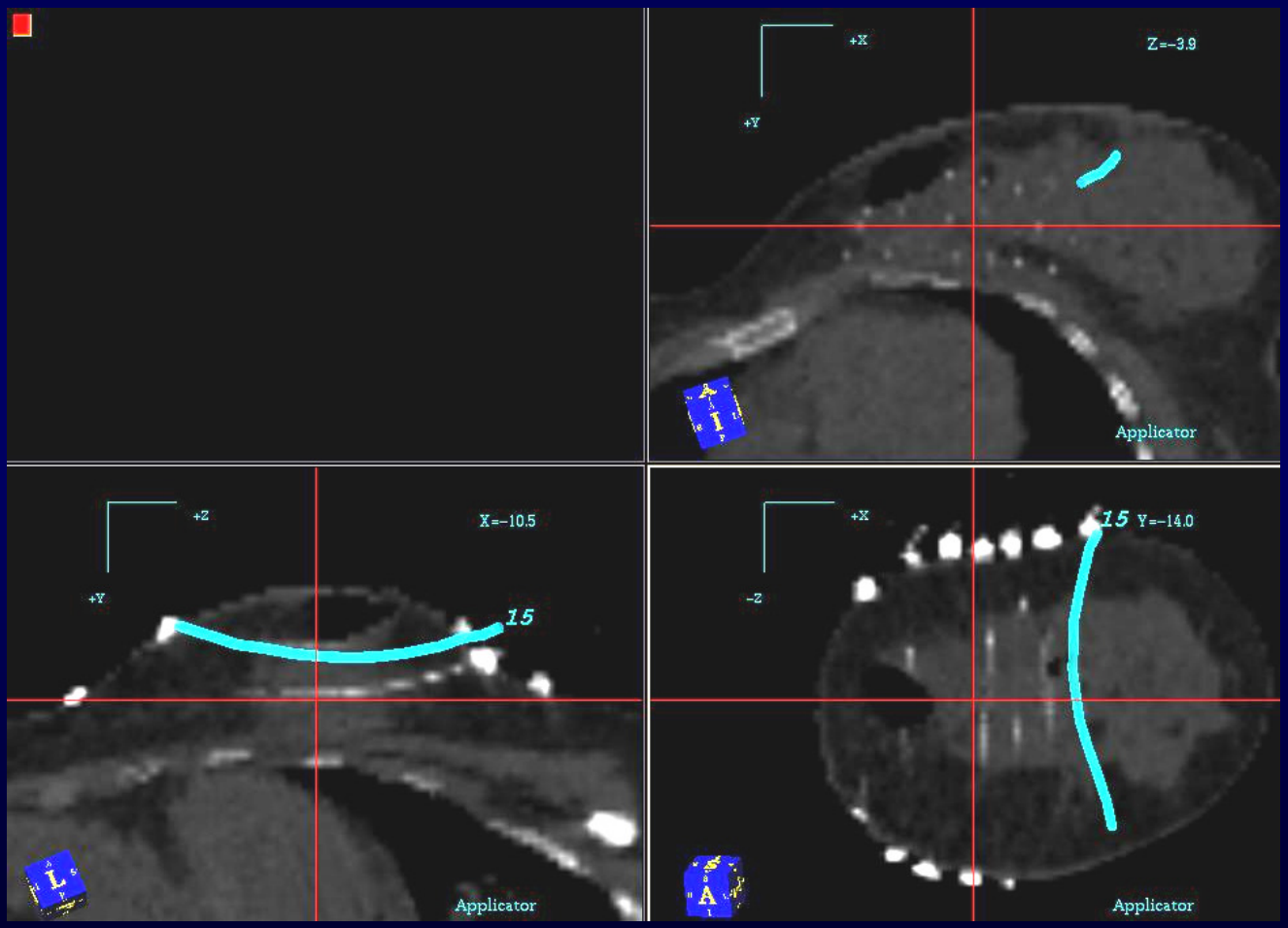
Catheter reconstruction

- Transverse CT cuts
- Multi planer reconstruction



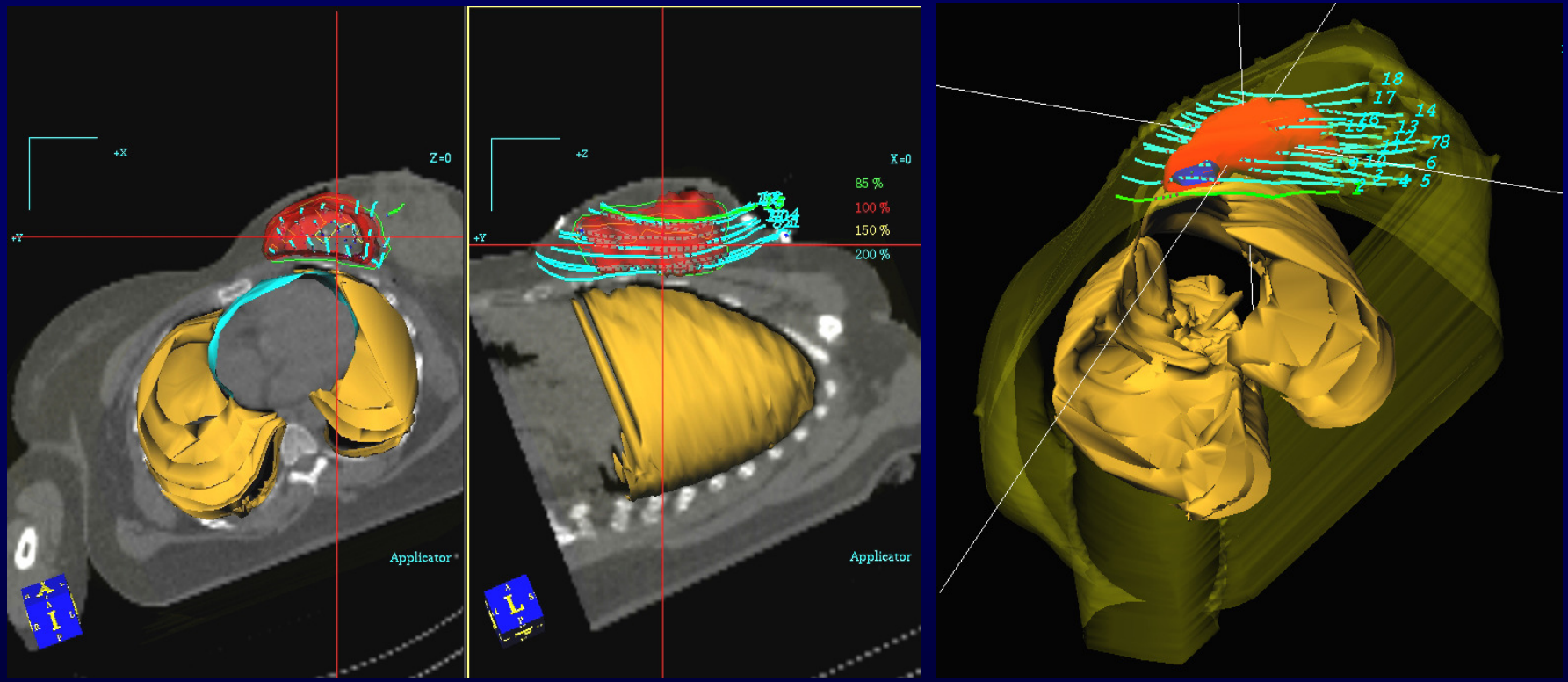
3D brachytherapy planning

Multi planer reconstruction (MPR)



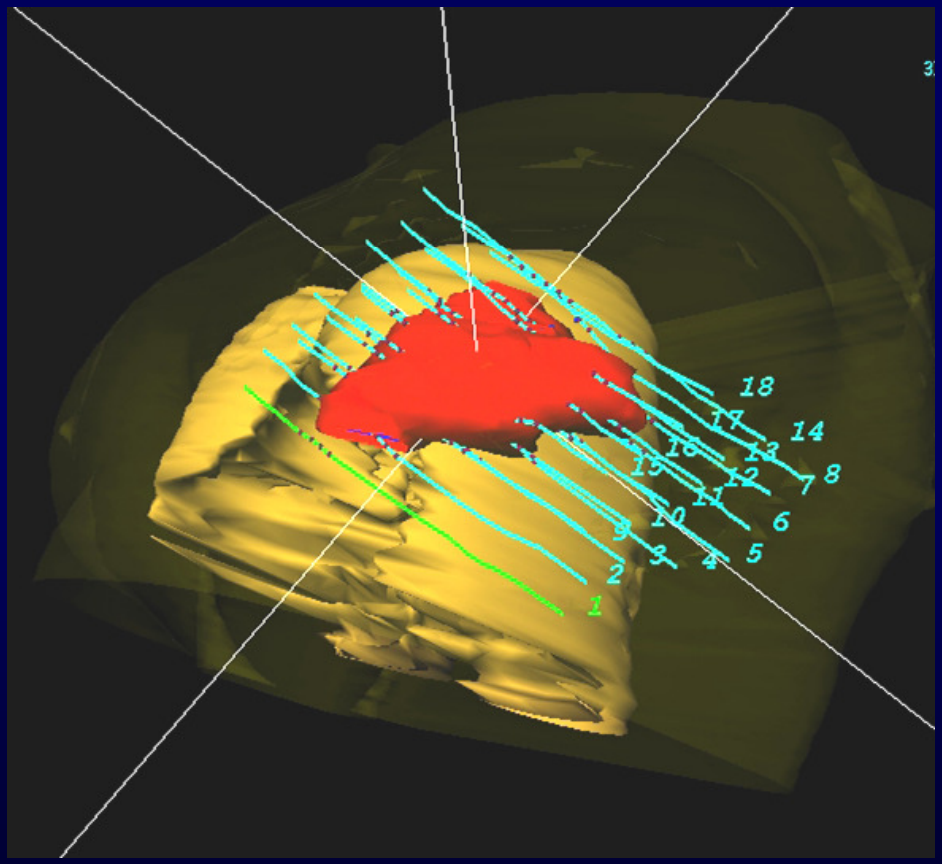
3D brachytherapy planning

Axial Sagittal 3D



3D brachytherapy planning

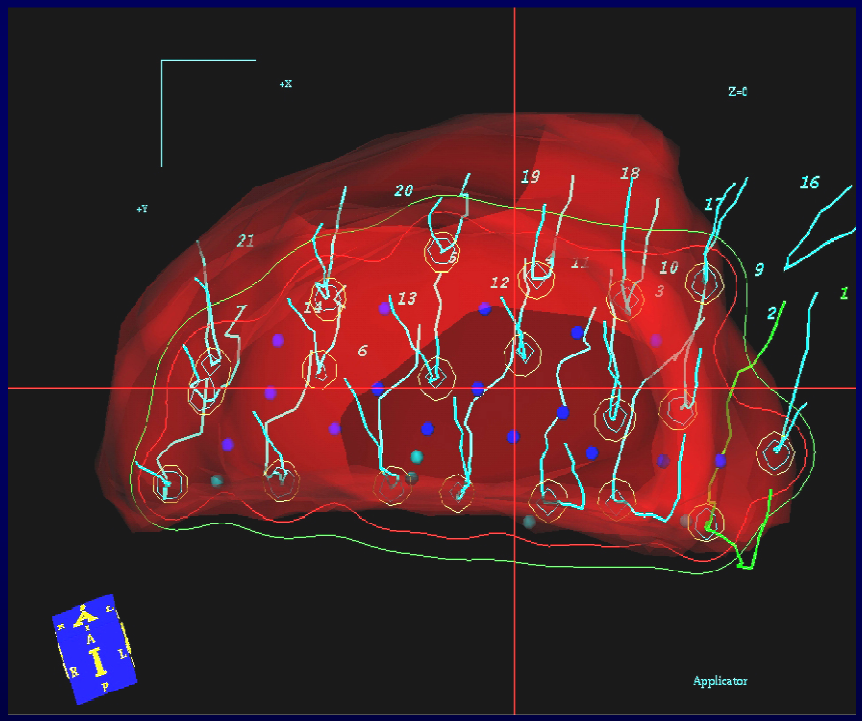
Determination of source loadings



3D brachytherapy planning

Prescription & Optimization

- 340 cGy / fraction at 85% of Basel dose
- Geometrical Optimization on volume



3D brachytherapy planning

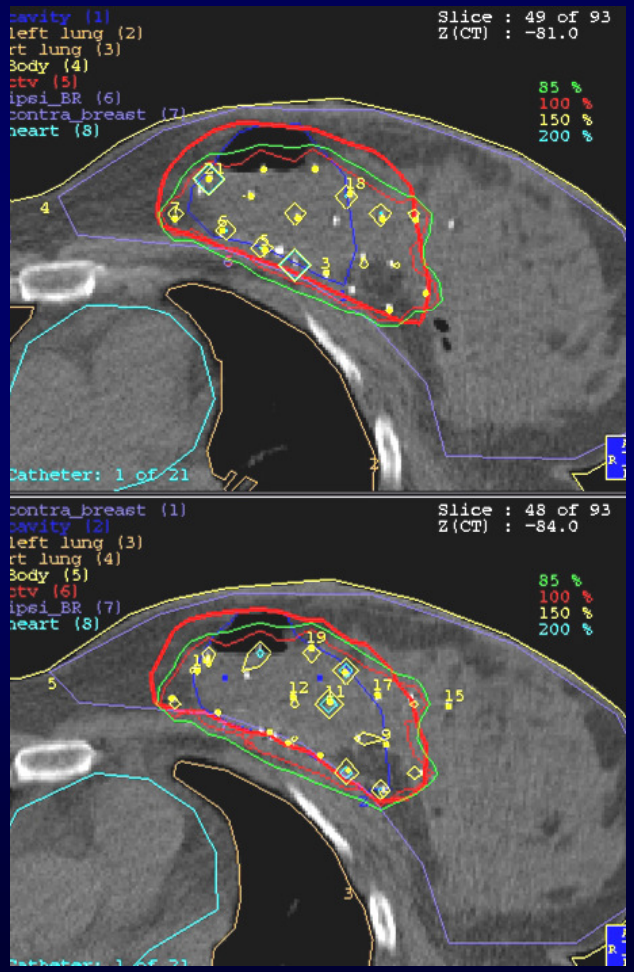
Graphical Optimization

It's a kind of manual optimization which allows to optimize dose distribution interactively on multiple planes by dragging the isodose lines

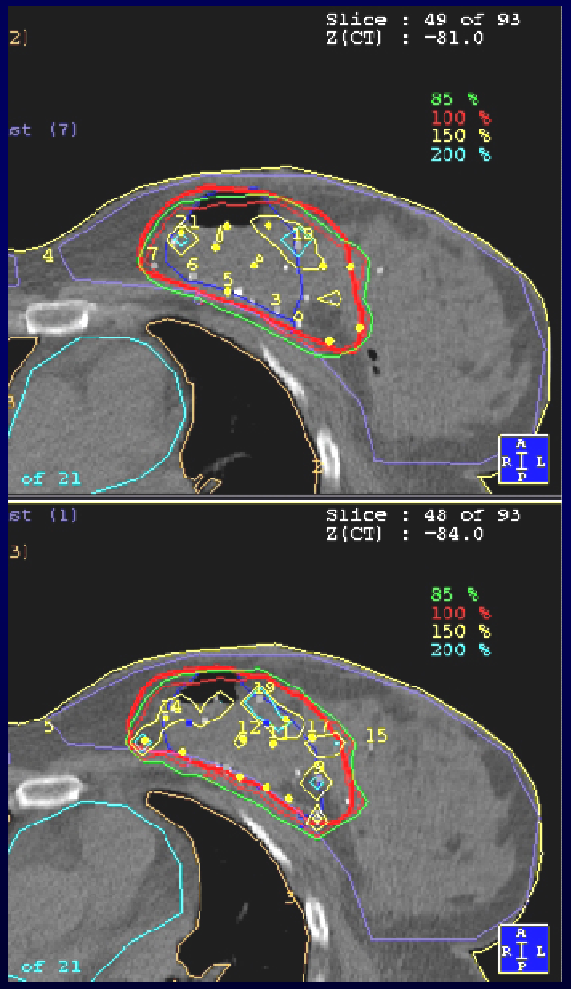
- To achieve dose distribution more conformal around the target
- To spare the dose to critical structure in acceptable limits

3D brachytherapy planning

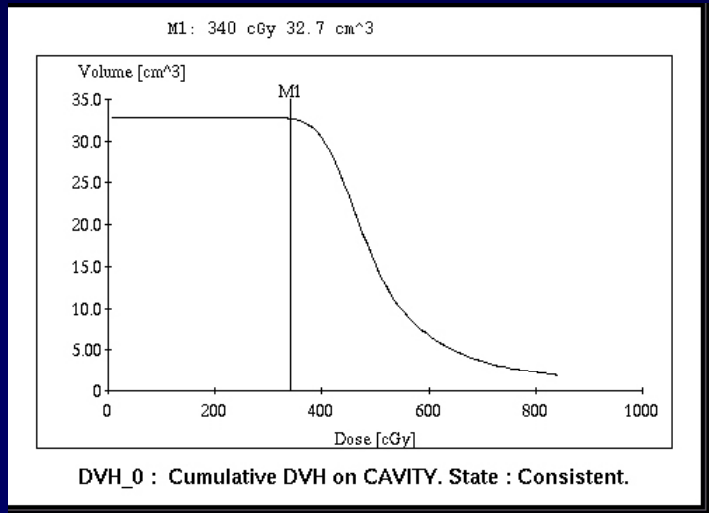
Geometrical Optimization



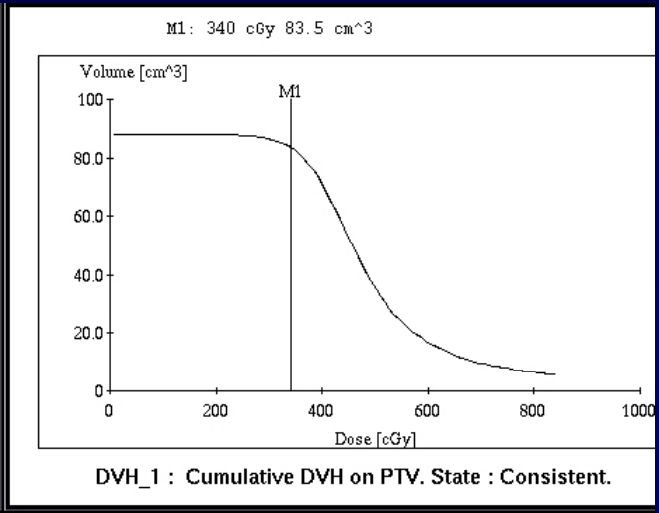
Graphical Optimization



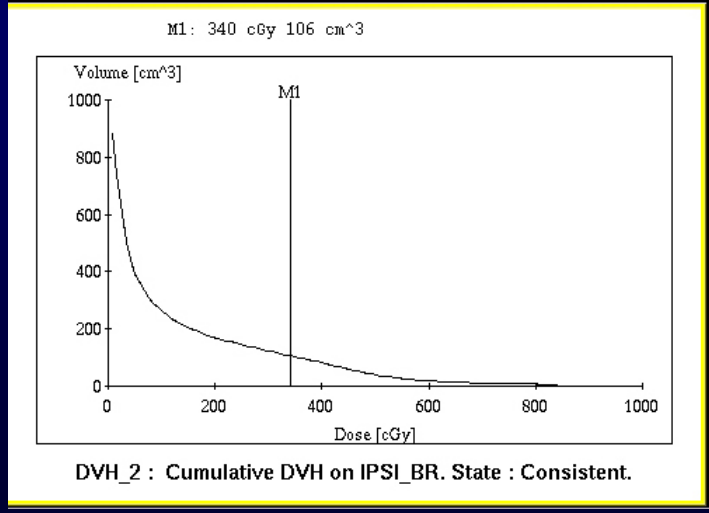
3D brachytherapy plan evaluation



DVH_0 : Cumulative DVH on CAVITY. State : Consistent.



DVH_1 : Cumulative DVH on PTV. State : Consistent.



DVH_2 : Cumulative DVH on IPSI_BR. State : Consistent.

Cumulative DVH of

Implant

Cavity

PTV

Other organs

3D brachytherapy plan evaluation

DVH of implant geometry

- Dose Homogeneity Index = $(V_{100\%} - V_{150\%})/ V_{100\%}$
- DHI > 0.75
- V150 < 70 cc
- V 200 < 20cc
- Dose to marker points

- Target coverage: > 90% of the PTV is covered by 90% of the prescribed isodose line
- <60% of the whole breast reference volume should receive >50% of the prescribed dose.

3D brachytherapy plan evaluation

Normal tissue tolerances

- Contralateral breast: <3% of the dose to any prescribed point.
- Ipsilateral lung: <15% of the lung to receive 30% of the prescribed dose
- Contralateral lung:< 15% of the lung to receive 5% of the prescribed dose.
- Heart: <5% of the heart to receive 5% of the prescribed dose

DVH Analysis

Coverage Index $CI = PTV_{100\%} / V_{PTV}$

Homogeneity index $HI = (V_{100\%} - V_{150\%}) / V_{100\%}$

Over dose volume Index $OI = PTV_{200\%} / V_{PTV}$

External volume Index $EI = (V_{100\%} - PTV_{100\%}) / V_{PTV}$

Conformal index:

COIN=C1×C2

$$c_1 = \frac{PTV_{ref}}{PTV}$$

$$c_2 = \frac{PTV_{ref}}{V_{ref}}$$

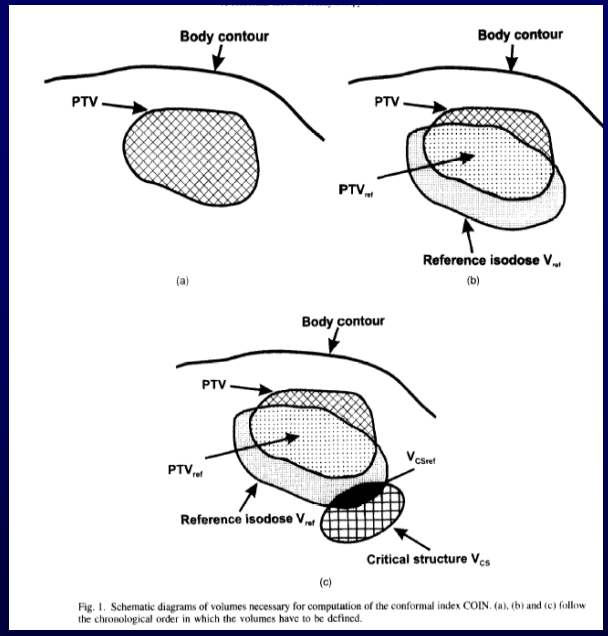


Fig. 1. Schematic diagrams of volumes necessary for computation of the conformal index COIN. (a), (b) and (c) follow the chronological order in which the volumes have to be defined.

Balta et al IJROBP 40,1998

Dosimetric comparison study

Clinical Oncology (2008) **20**: 46–52
doi:10.1016/j.clon.2007.09.006

Original Article

Dosimetric Comparison of Conventional Radiograph- and Three-dimensional Computed Tomography-based Planning using Dose Volume Indices for Partial Breast Intraoperative Implants

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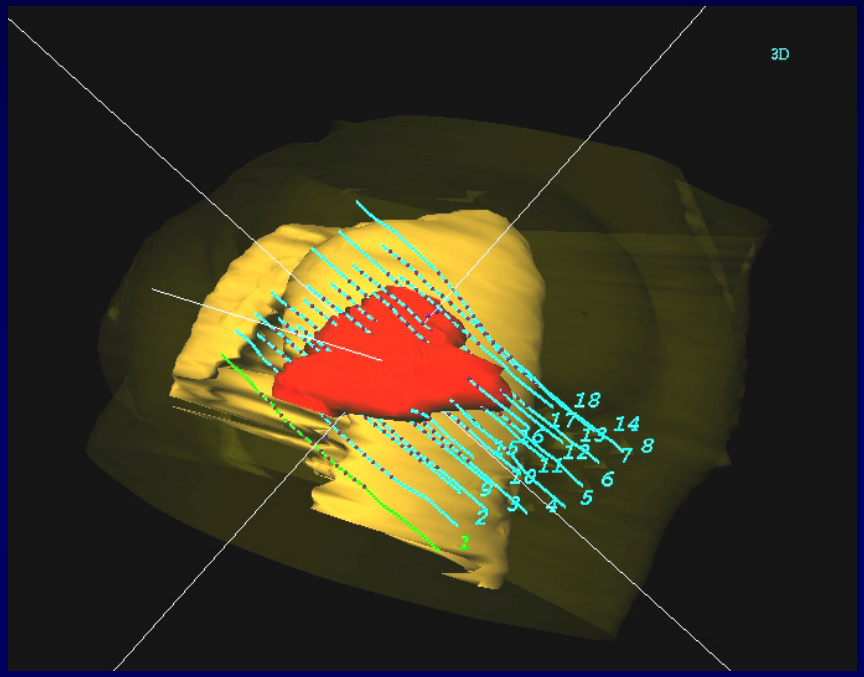
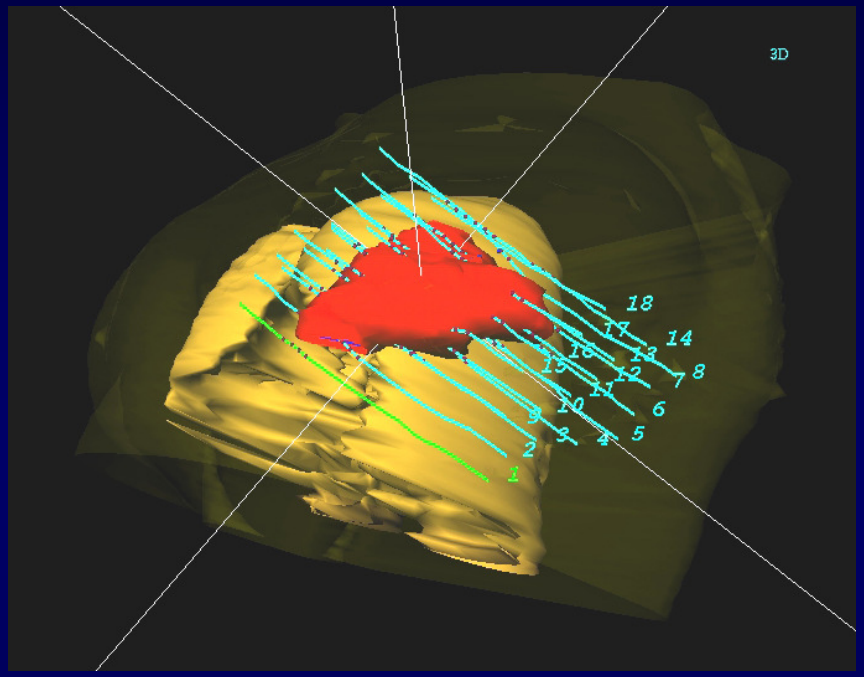
18 Consecutive APBI patients

X-ray plan, Geometrical optimization & Graphical optimization

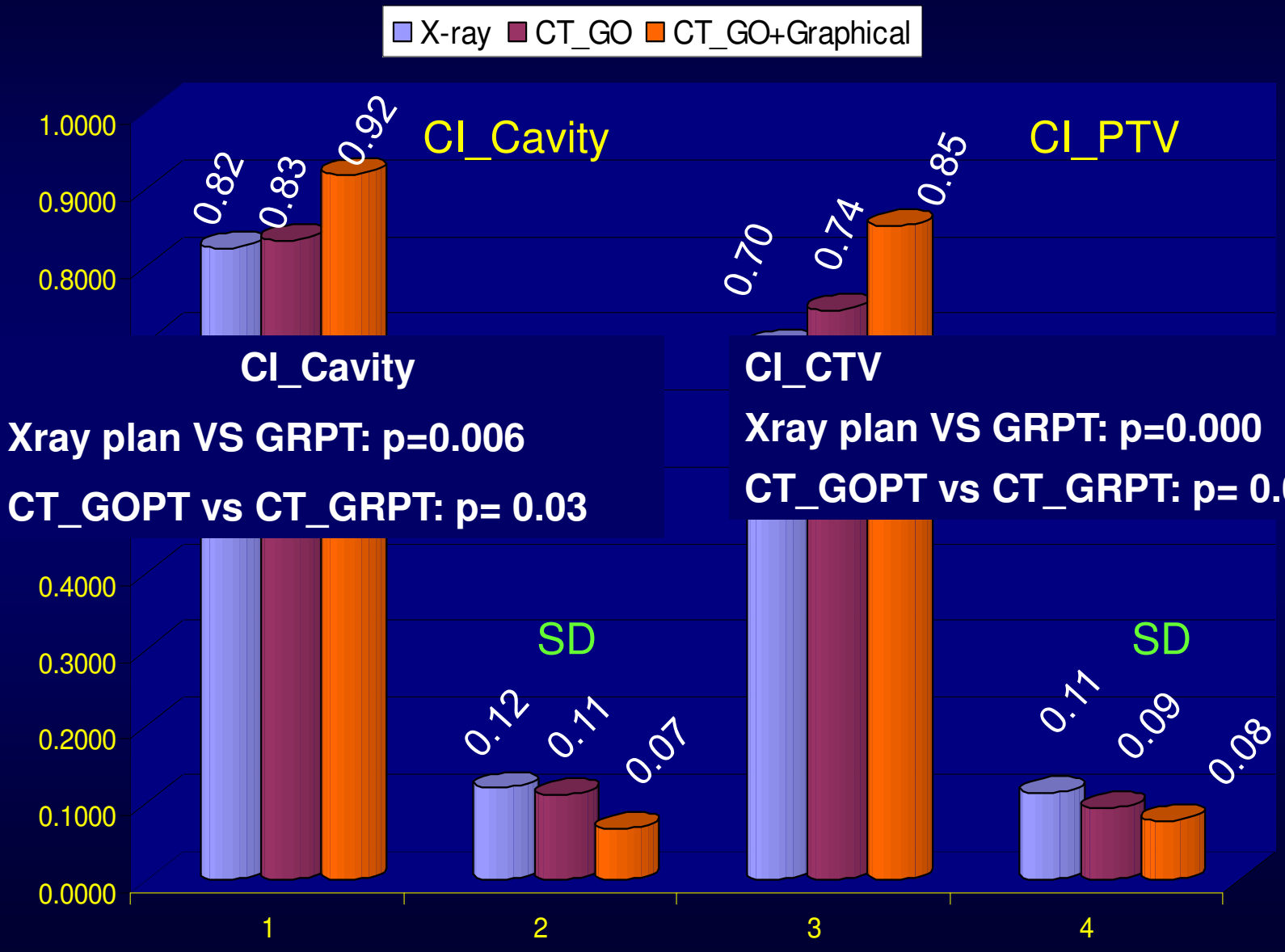


Loading based on
X ray information

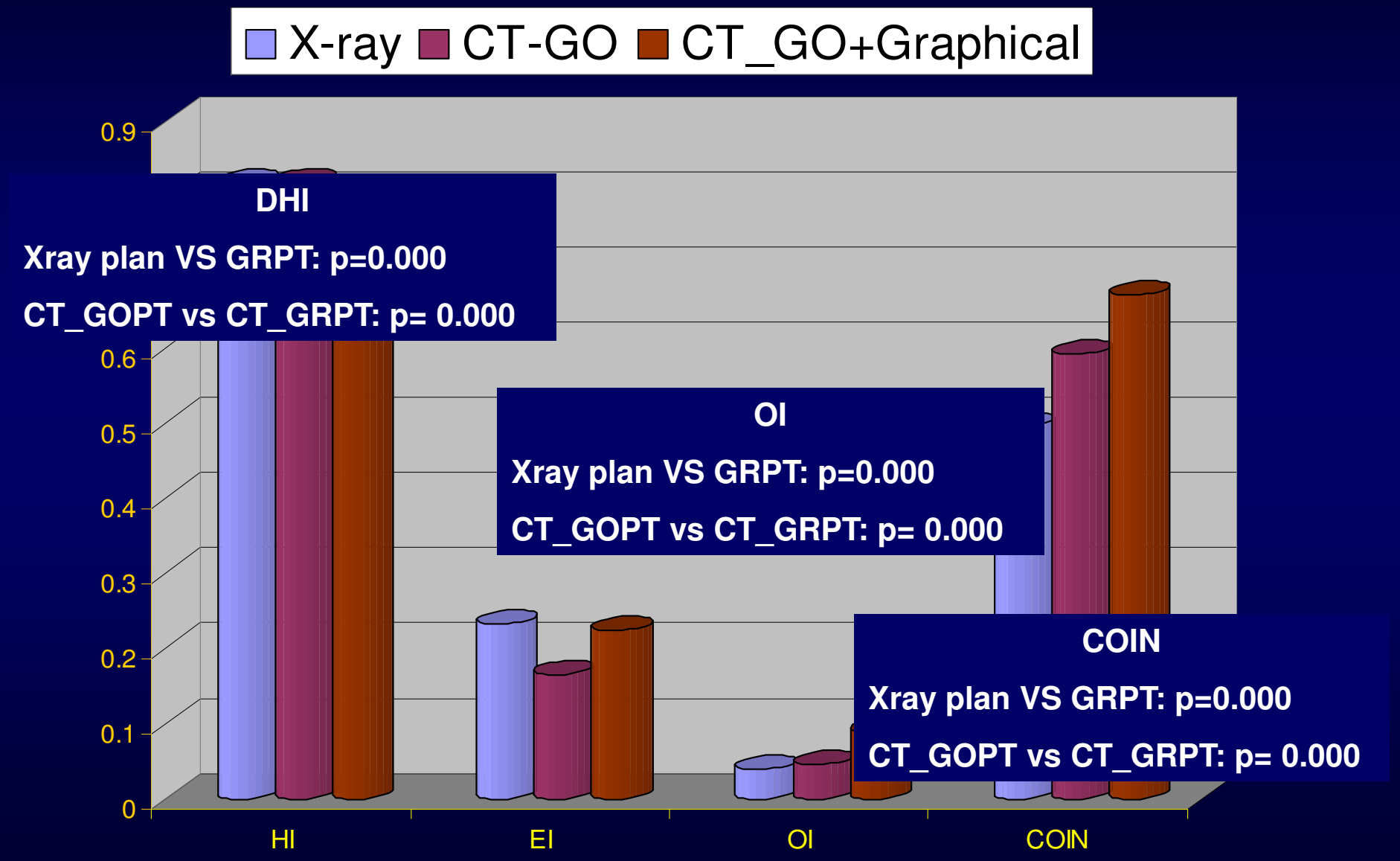


Loading based on
CT information

CI for cavity and PTV



DHI, OI and COIN



Summary

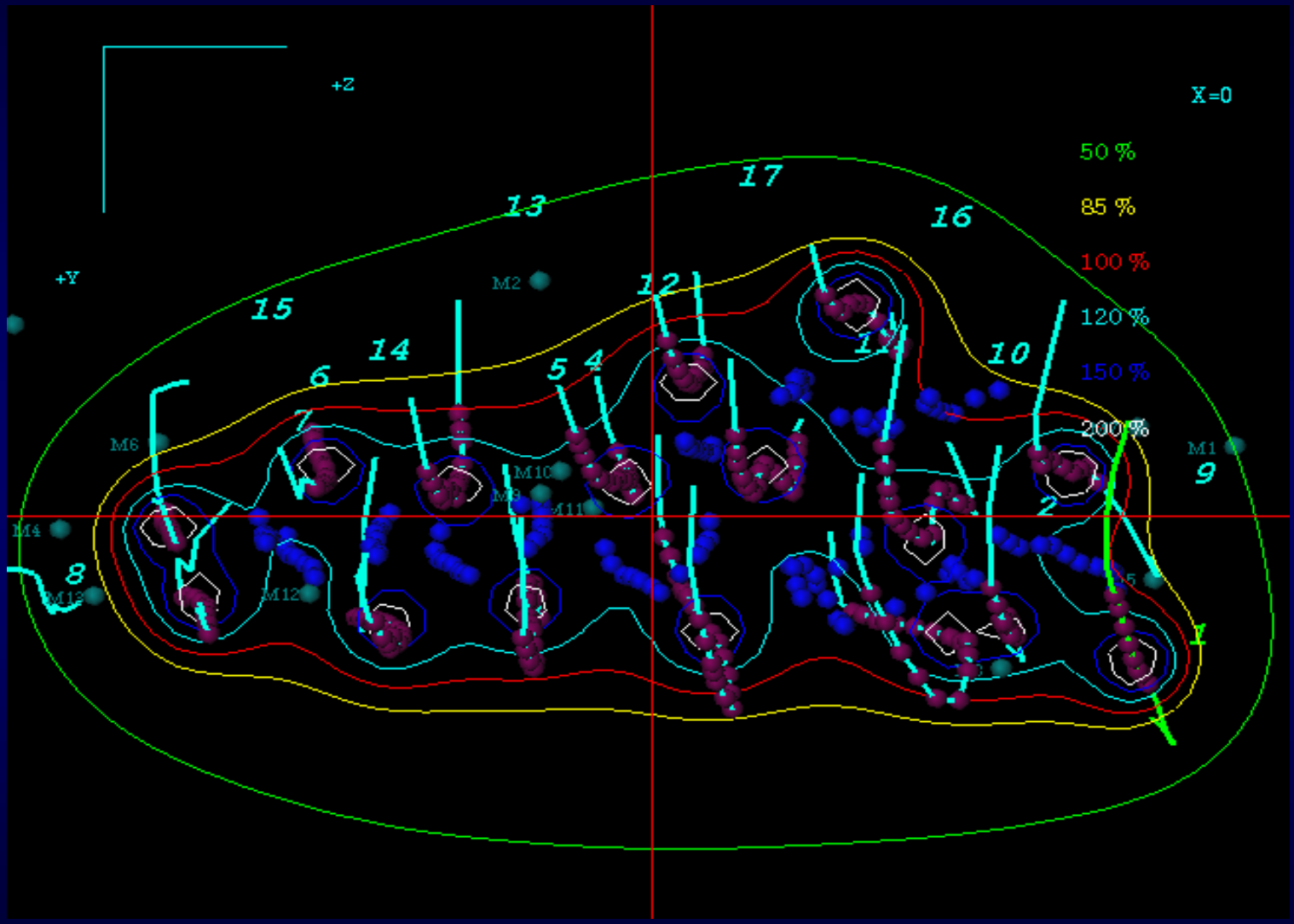
CT based 3D brachytherapy is superior over conventional planning

3D brachytherapy plan provides more conformal distribution

Dose reduction to normal breast

Clinical realistic evaluation of implant dosimetry by DVH analysis

Thank You


+Z
X=0
50 %
85 %
100 %
120 %
150 %
200 %
+Y
13
17
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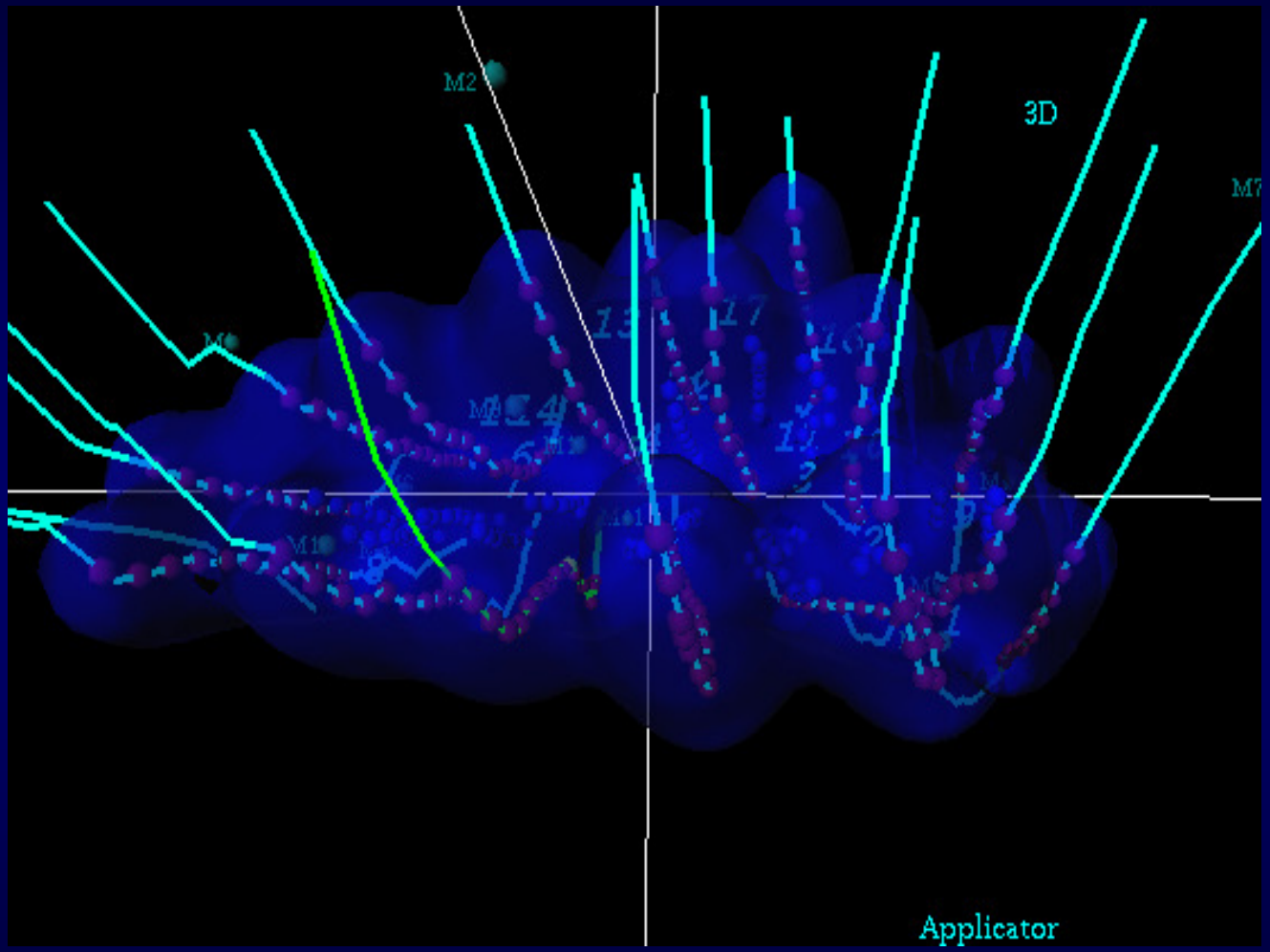
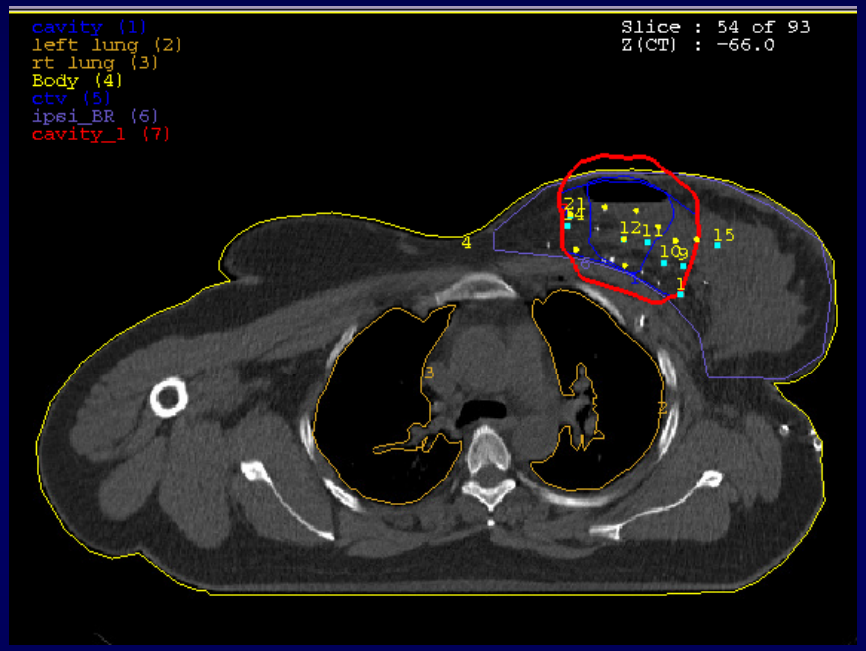

M2
3D
M7
Applicator

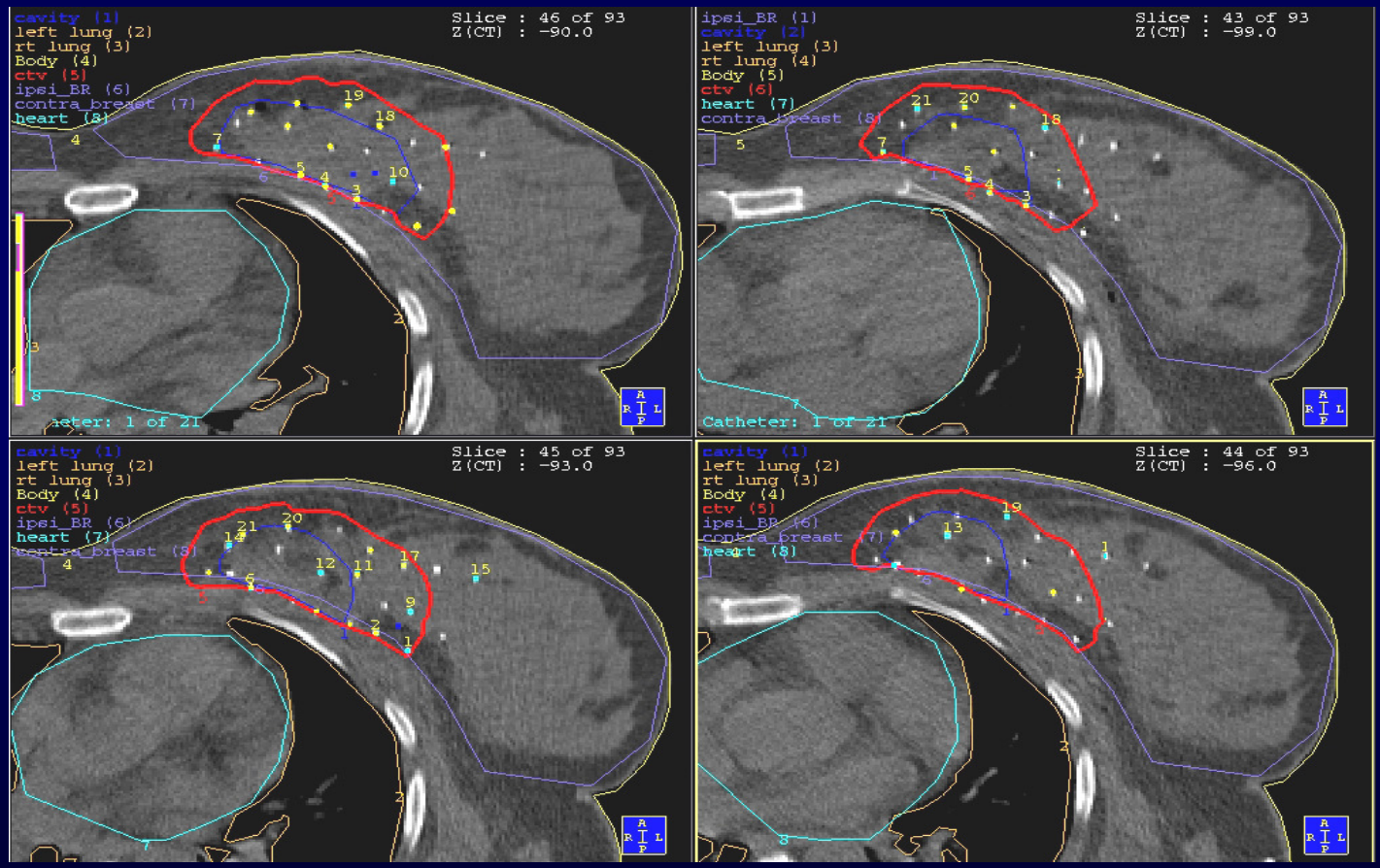
Brachytherapy Planning
3D Planning: Contouring

- Clinical Target Volume (CTV): Is drawn by uniform expansion of the cavity by 1-2 cm
- CTV is further edited for skin and chest wall
- Skin: CTV is taken 5mm inside the skin
- Chest wall: CTV is edited so that it is just above the pectoral muscle.

- For Brachytherapy : CTV=PTV



Brachytherapy Planning
3D Planning: Contouring

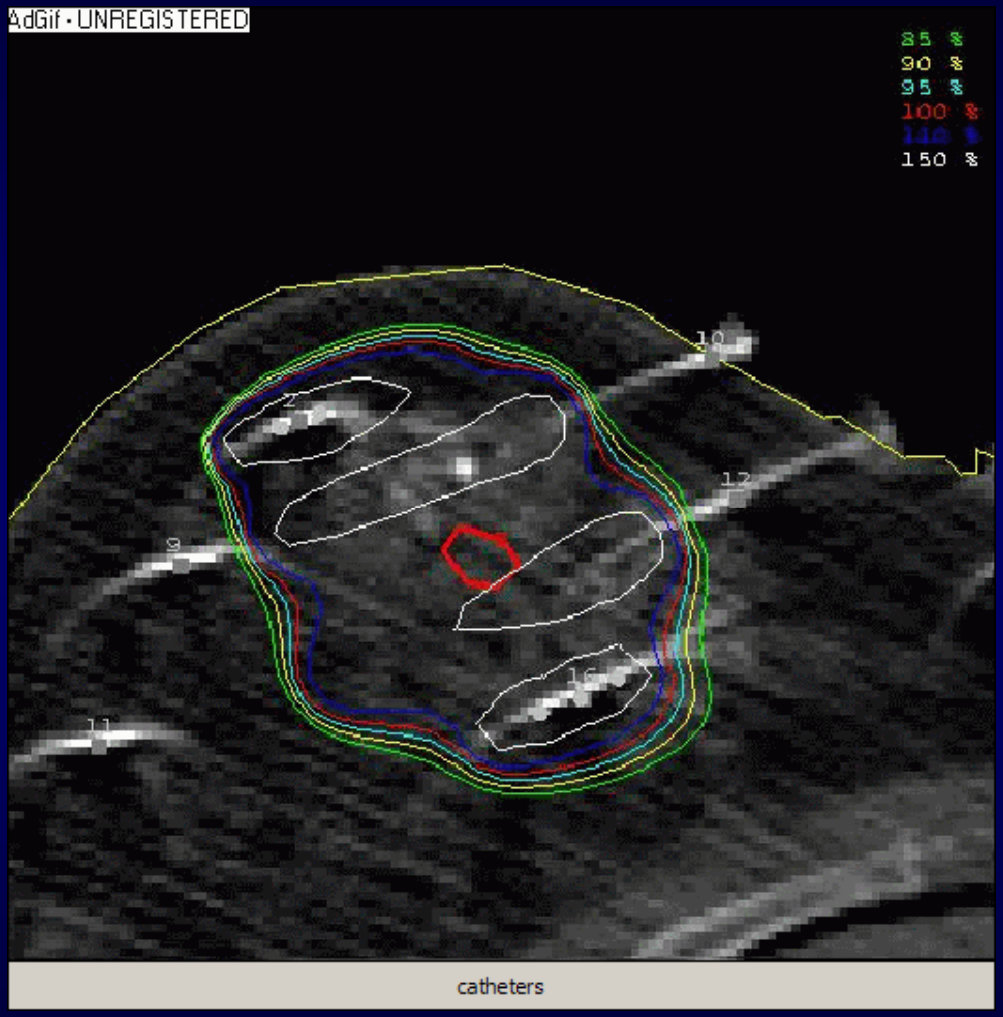


3D Brachytherapy Planning
: Contouring of normal structures

- Heart: Contouring should begin at the level where the pulmonary trunk diivides into right and left braches
  - All the mediastinal structures below this level to be contoured including great vessels
  - Heart should be contoured till the last cut where it touches the diaphram.

- Lungs: Both lungs to be contoured based on the visibility. Automated tools can be used for contouring

- Normal Breast : Ipsilateral and Contralateral
  - All the breast tissue between the midline medially and midaxillary line laterally to be contoured.
  - Posterior border to be formed be formed by chest wall.


AdGif - UNREGISTERED
85 %
90 %
95 %
100 %
150 %
10
12
9
11
catheters

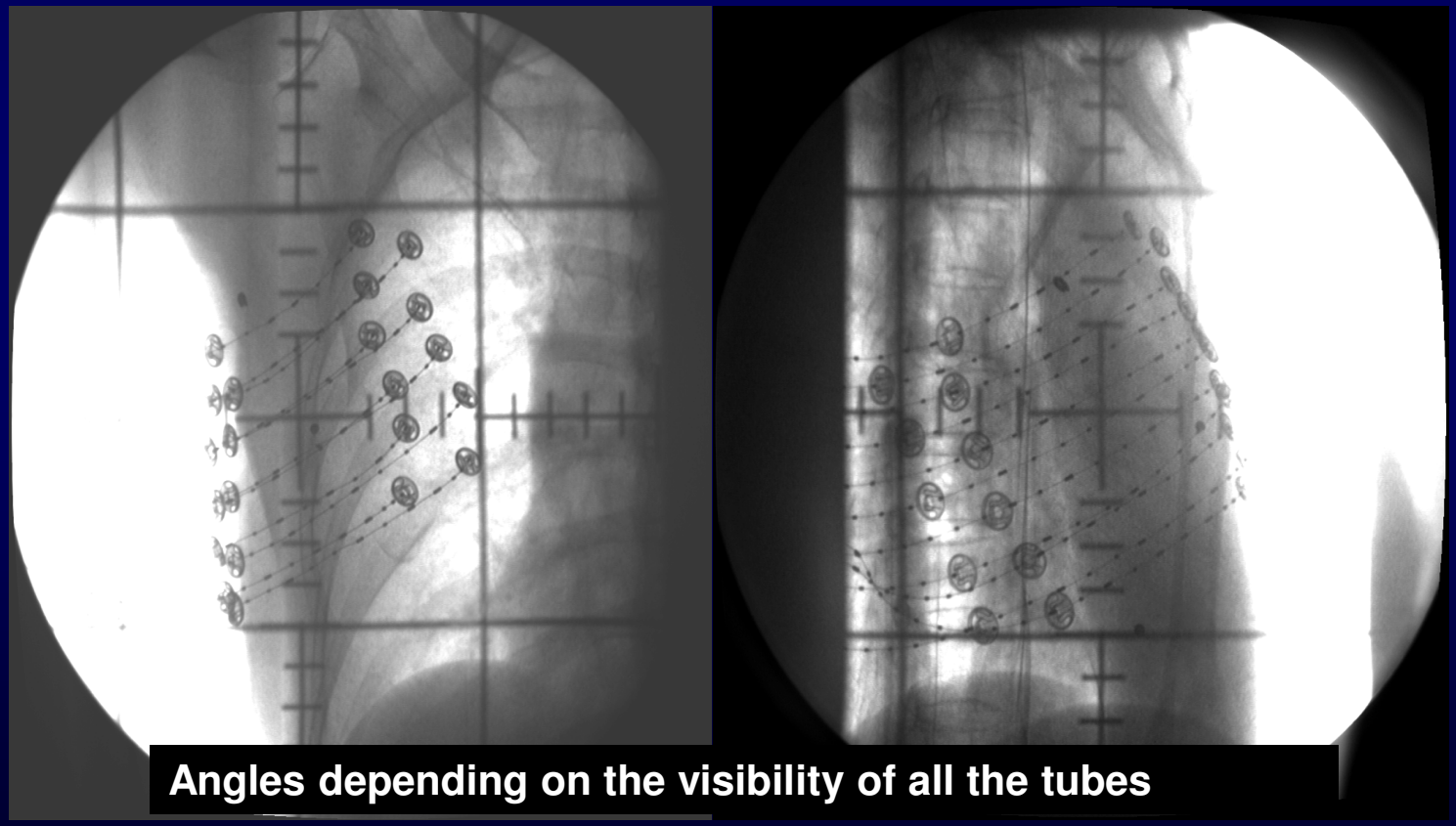
RTOG Criteria for dose evaluation: APBI

- 95% Isodose line should cover 100% of the PTV
- Uninvolved normal breast:
  - <50% of normal breast should receive >50% of prescribed dose
  - <25% of normal breast should receive the prescribed dose
- Ipsilateral Lung: <10% of the lung should receive 30% of the prescribed dose
- Contralateral breast: <3% of the prescribed dose to any point
- Heart: <5% of the heart should receive 5% of the prescribed dose

Radiograph based planning

Acquisition of radiographs:

Orthogonal or Variable angle



Angles depending on the visibility of all the tubes