Physics of Head and Neck Brachytherapy

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Sites of Head and Neck Brachytherapy

Interstitial

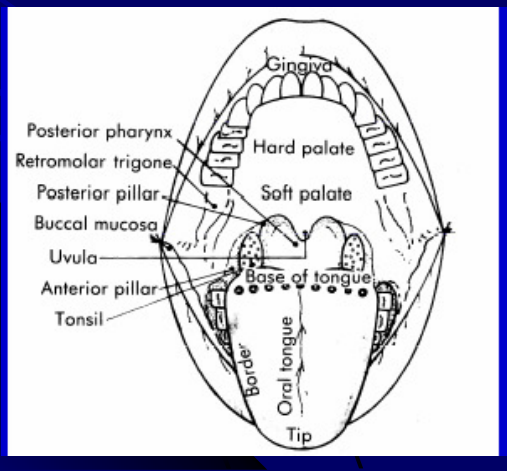
Lip
Buccal Mucosa
Tongue, Base tongue
Hard and soft palate

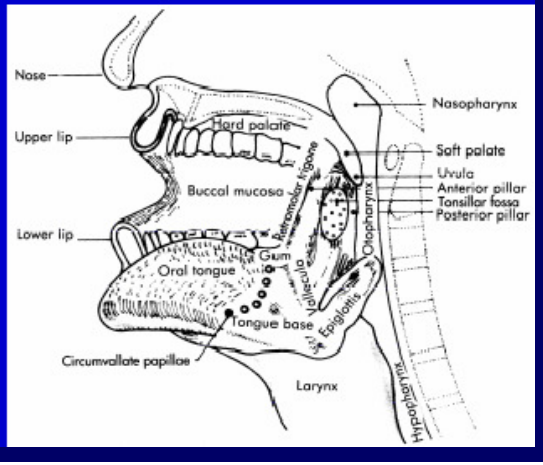
Surface mould

Nose
Face
Pinna
Ext.auditory canal

Endo cavitary

Nasopharynx

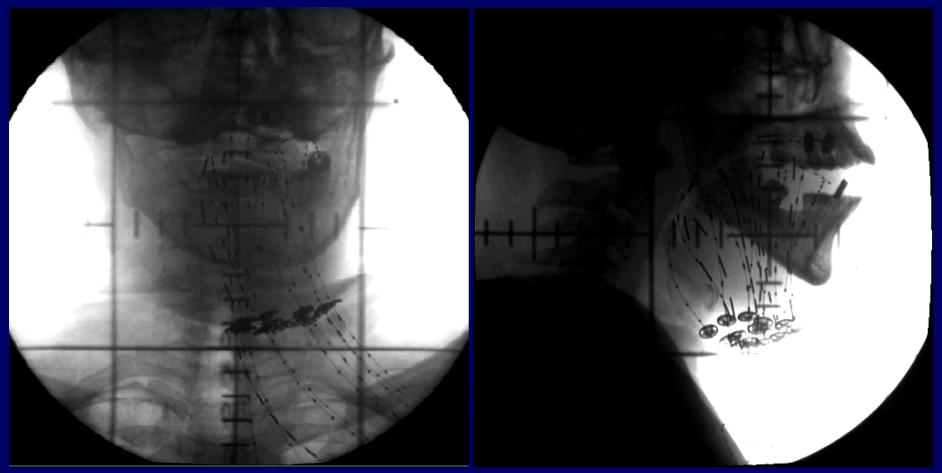


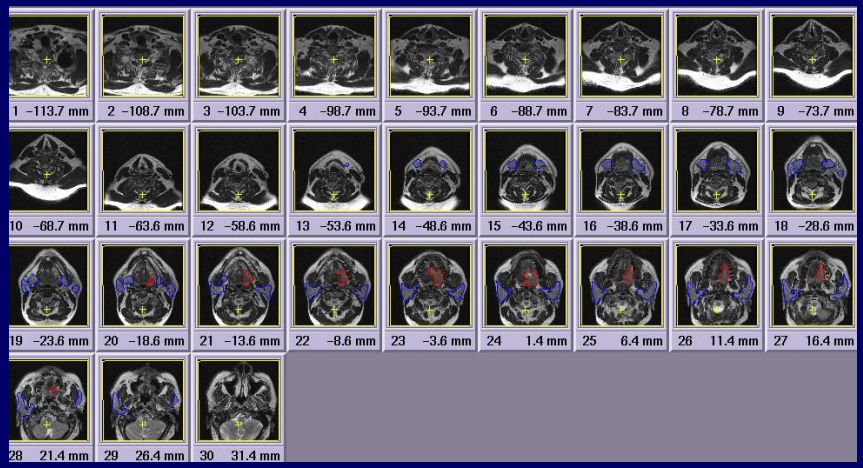


Head and Neck Implant dosimetry Workflow

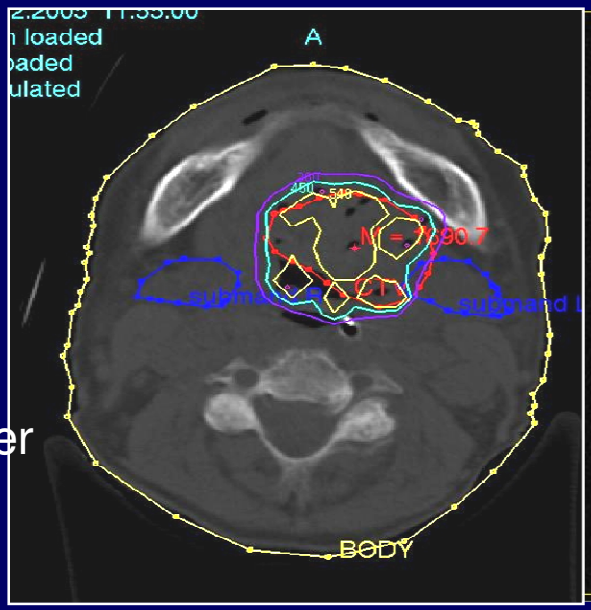
- Imaging
- Reconstruction & source activation
- Dosimetry systems
- Definition of dose points-prescription
- Optimization
- Evaluation

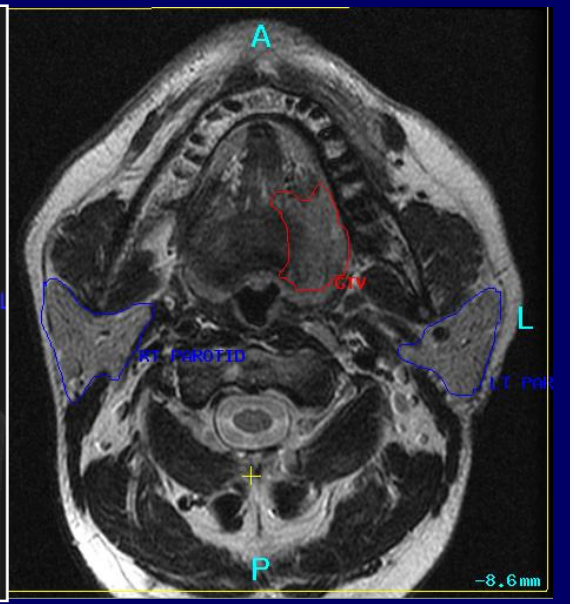
Imaging



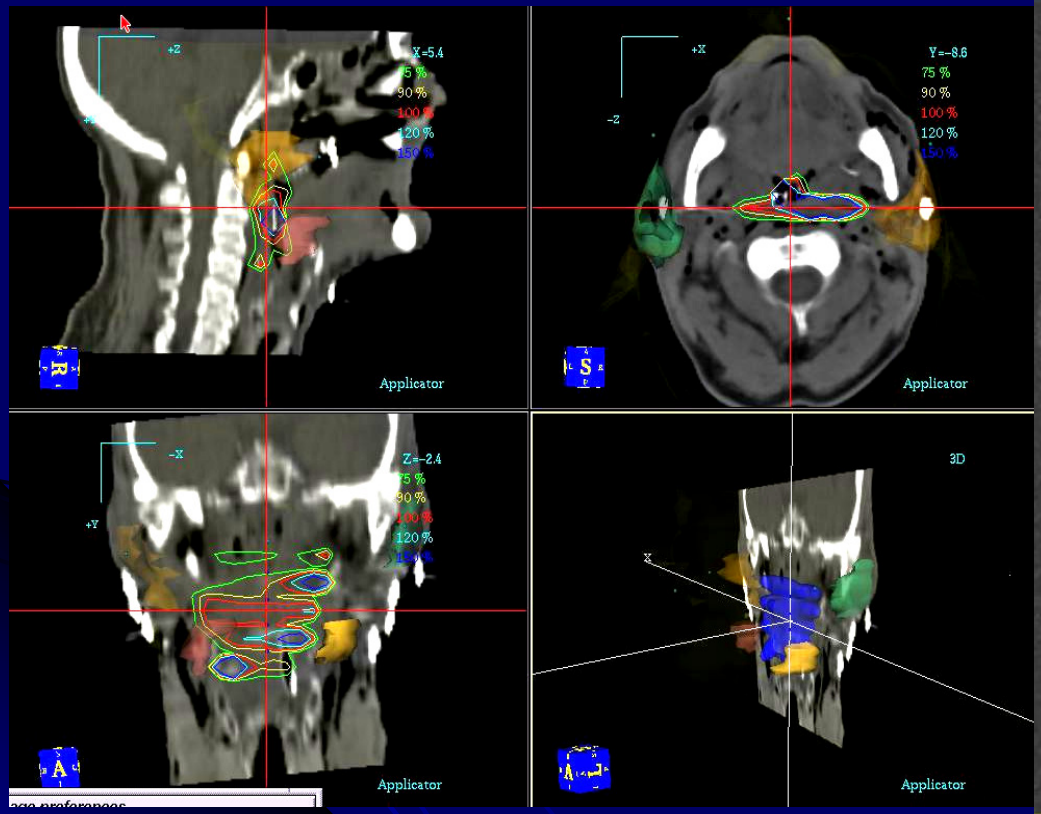


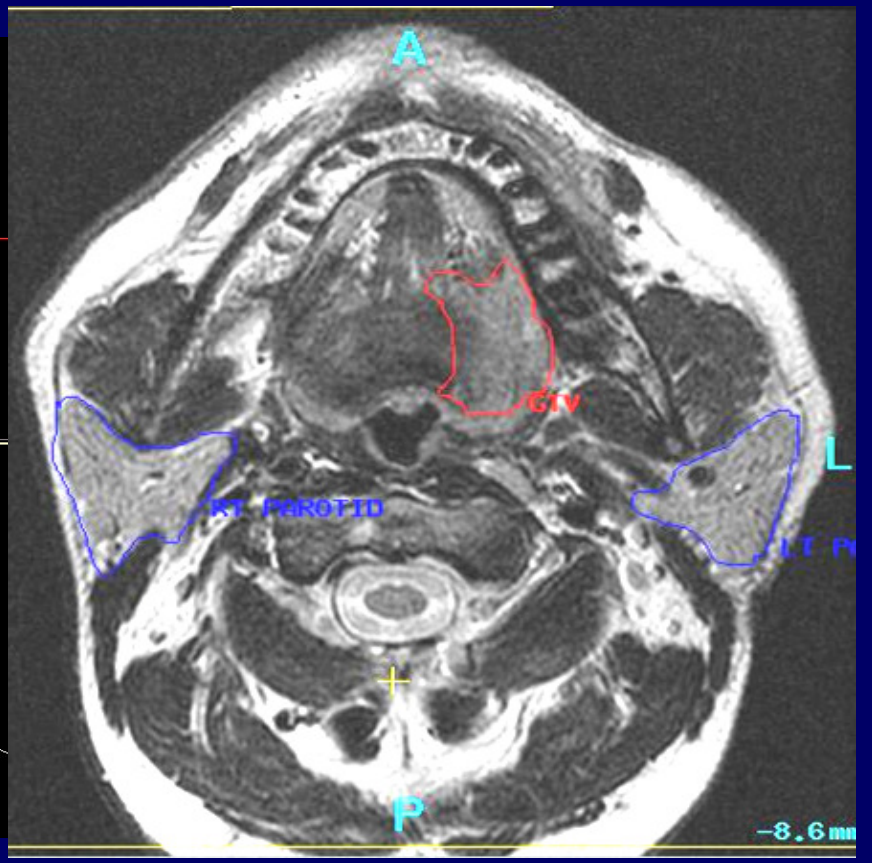
- Patient Position,
- Immobilization
  (no patient movement between the radiographs is allowed)
- Insertion of markers
- Check for kink etc
- Secure the buttons and the beads
- Dummy run with appropriate indexer
- Head first supine, no gantry tilt
- Axial images of 2-5mm





Target volume delineation (CT/MR)





In Radiographs markers are placed with clinical judgment during implantation which can be used to locate the target

Head and Neck Implant dosimetry

- Imaging
- Reconstruction & Source Activation
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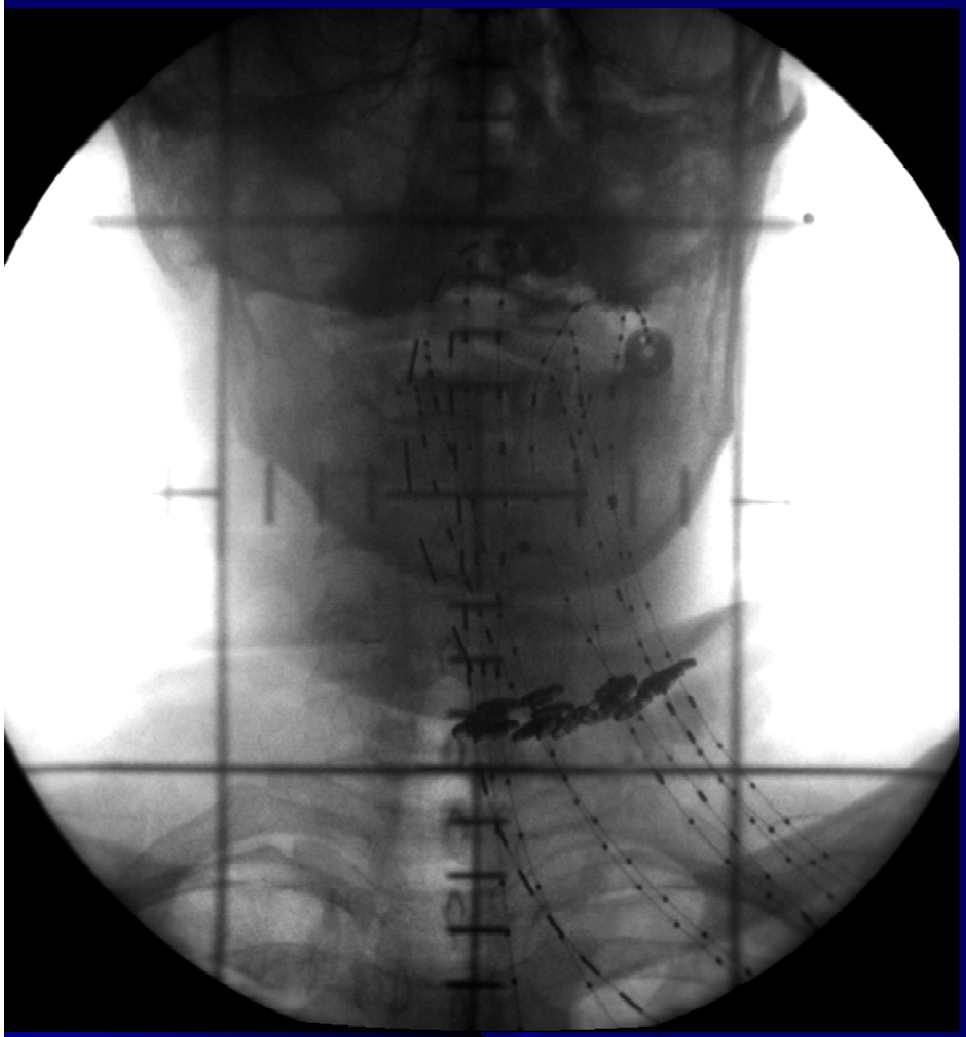
Reconstruction of implant geometry

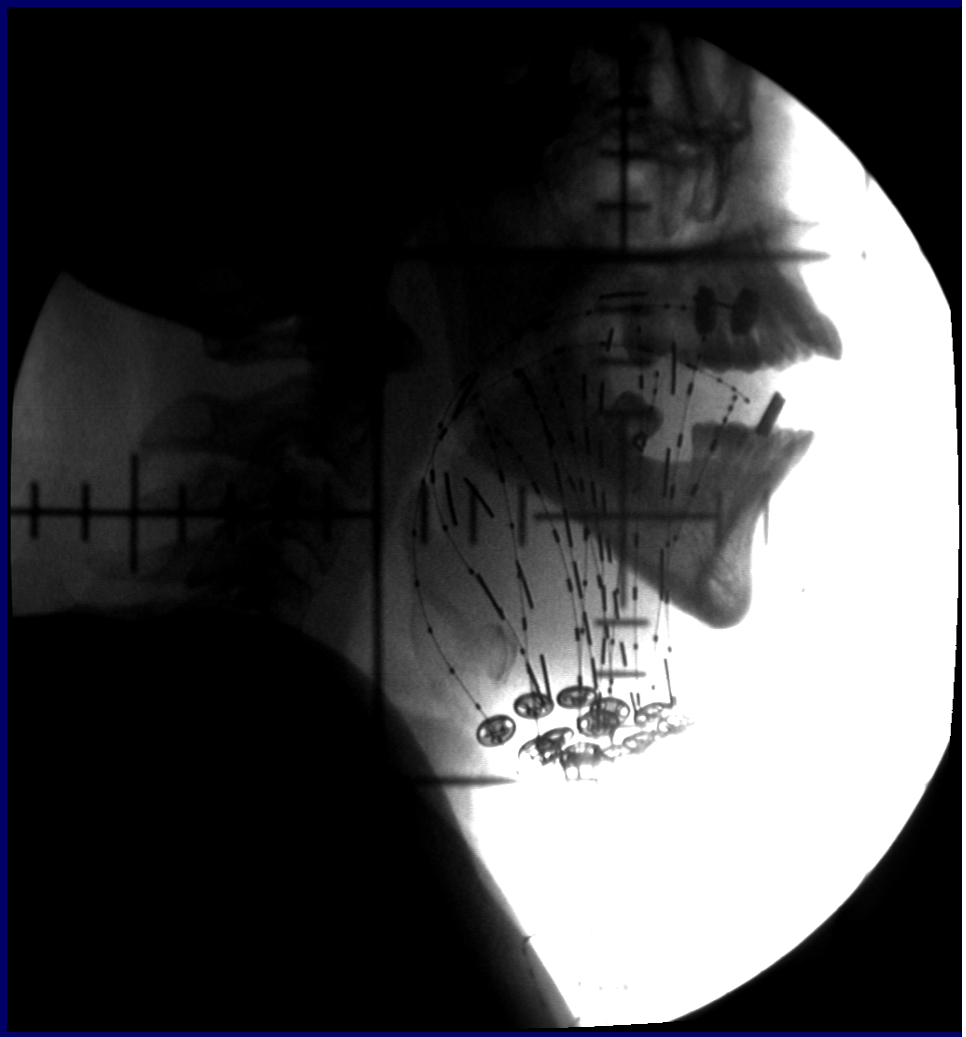
- A complex procedure, complexity increases with the number of catheters
- Accurate reconstruction is essential for accurate dosimetry
- 2mm error in reconstruction may cause a dose variation of 5-10%

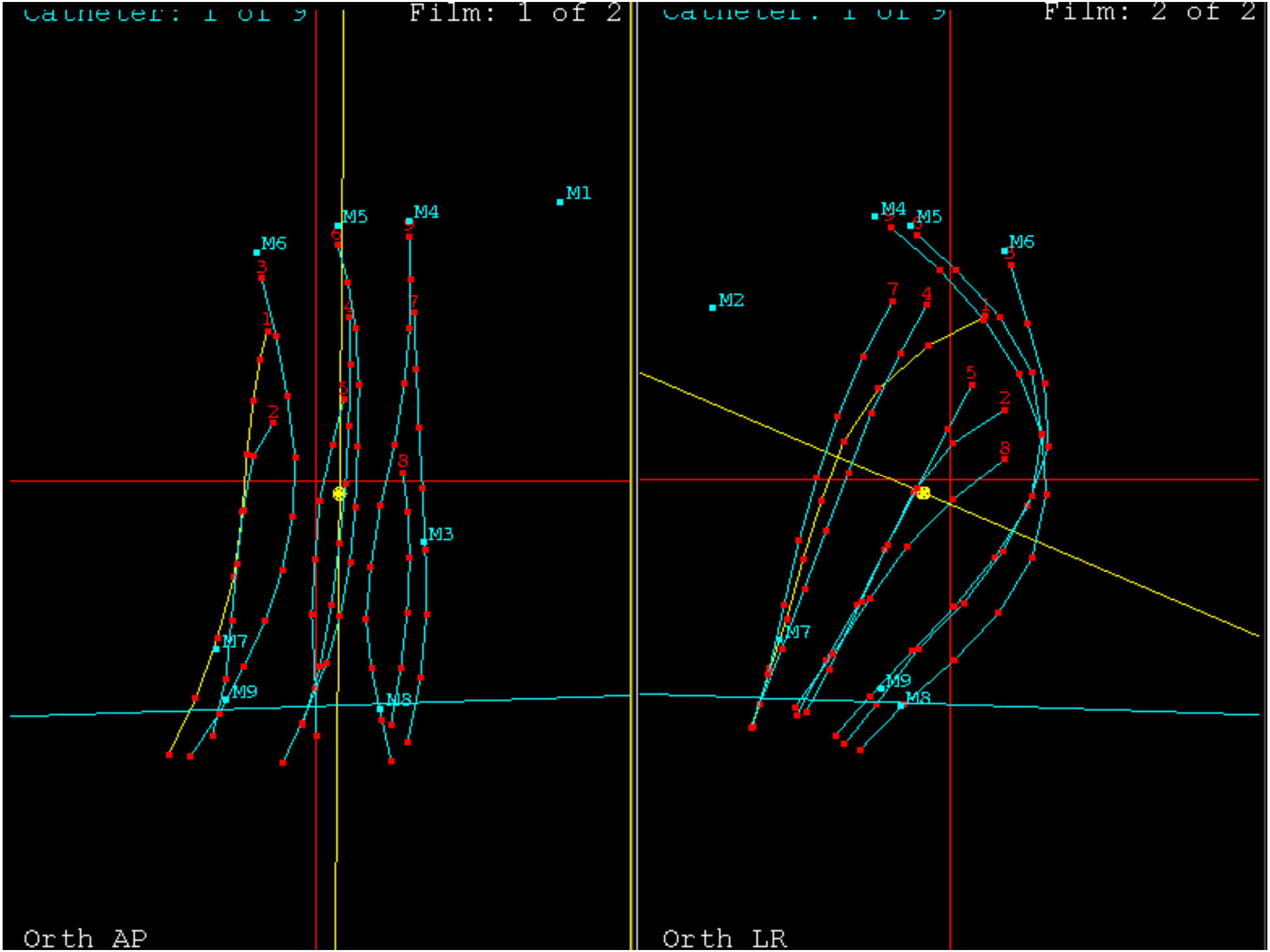
Radiograph- reconstruction

- Orthogonal radiograph images with dummies inserted in appropriate sequence
- Semi orthogonal / variable angle radiographs may be taken if some catheters are masked.
- Reconstruct markers (skin, target etc)
- First dwell position at a 4mm from the tip
- Consider more points in the curvature.

Orthogonal images





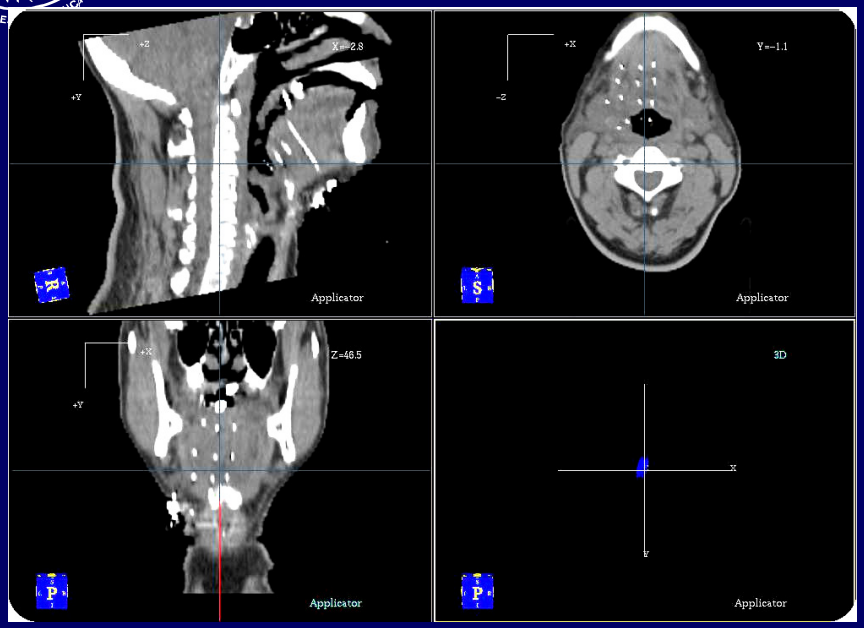

Catheter: 1 of 9
Film: 1 of 2
M1
M2
M3
M4
M5
M6
M7
M8
M9
Orth AP
Catheter: 1 of 9
Film: 2 of 2
M4
M5
M6
M2
M7
M9
M8
Orth LR

CT/MR reconstruction

Multiplanar reconstruction (MPR)

- TPS accepts only axial images, no coronal and saggital raw images can be used by TPS for recon.
- Acquire images in true axial (3mm/5mm slice thickness)
- from the 3D image, coronal, sagittal, and axial sections can be reconstructed, which is used for MPR.
- First dwell position cannot be seen, offset can be calculated from the radiograph with appropriate dummies.

MPR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Y=-1.1
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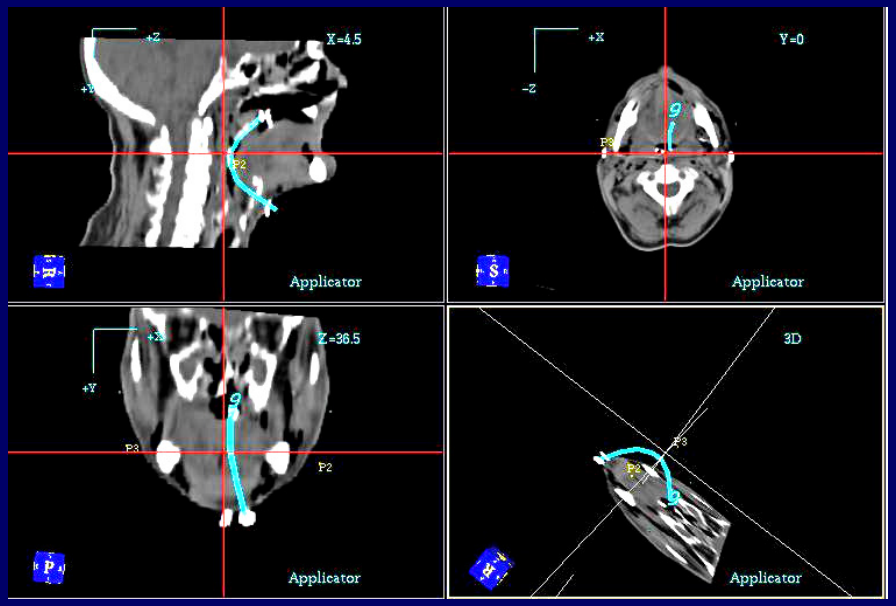
3D
Applicator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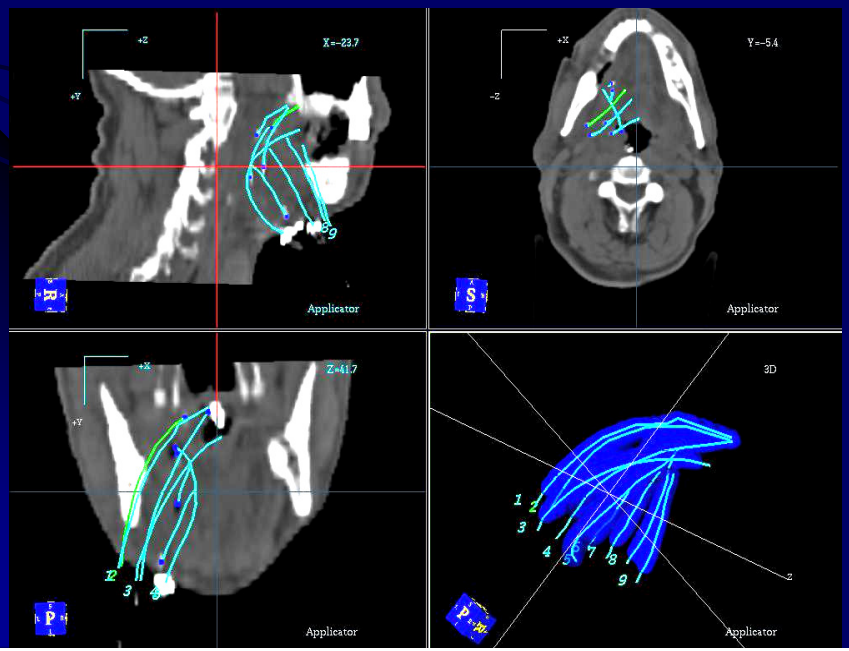
Y=0
Z=36.5
3D
P2
P3
Applicator


X=-23.7
Y=-5.4
Z=41.7
3D
1
2
3
4
5
7
8
9
Applicator

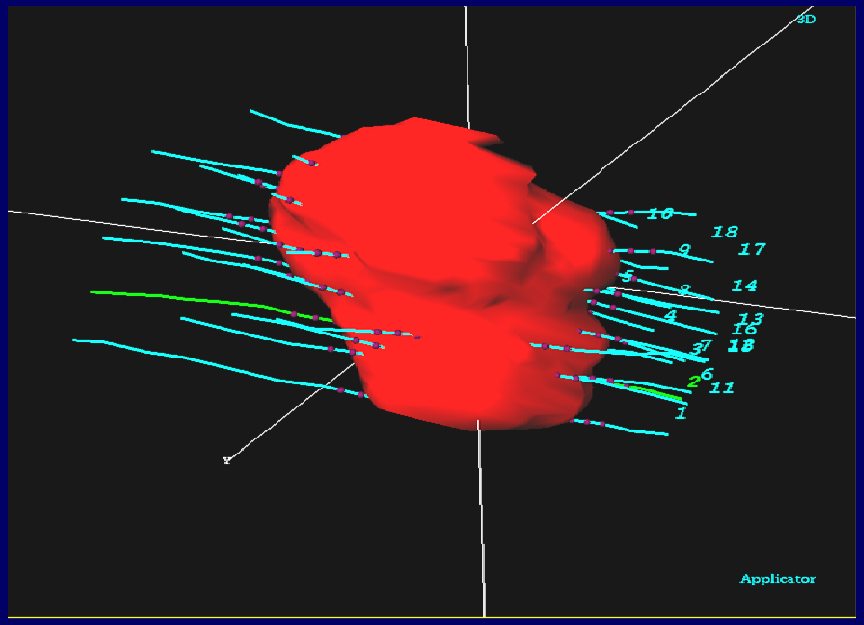
Source Activation

Traditional

- Load the entire implanted catheter excluding the margins for the skin (5-10mm)

Modern conformal Brachy:

- Load such that CTV is sufficiently covered with margins



Head and Neck Implant dosimetry

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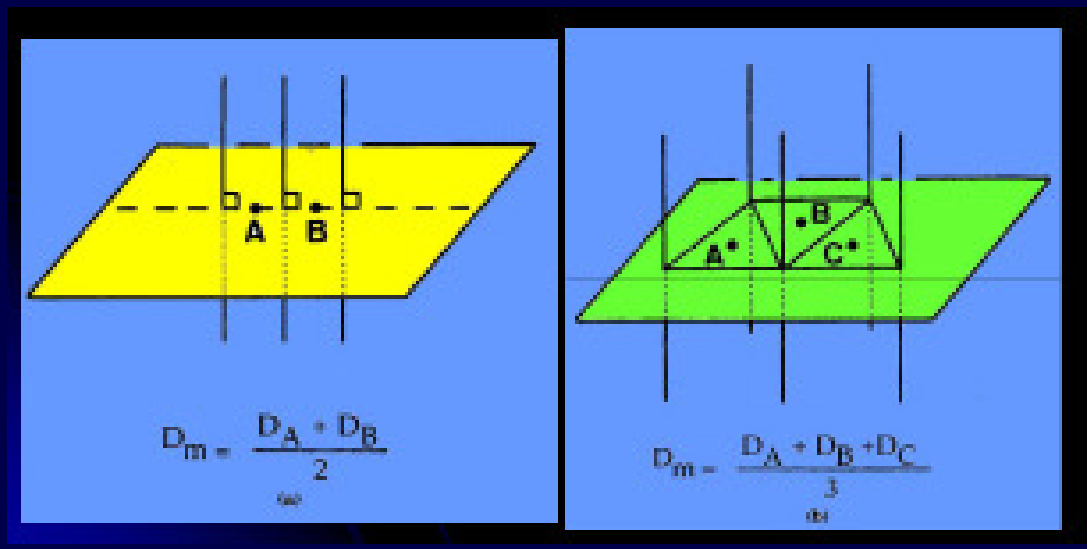
Dosimetry

- Manchester
- Quimby
- Paris systems
- Stepping Source Dosimetry Systems (SSDS)

Paris system

- Linear activity of the sources must be uniform along the catheters
- Sources must be straight, parallel and equidistant from each other
- Basal dose rate is the average lowest dose rate
- Reference doserate is 85% of basal dose rate



Paris system…

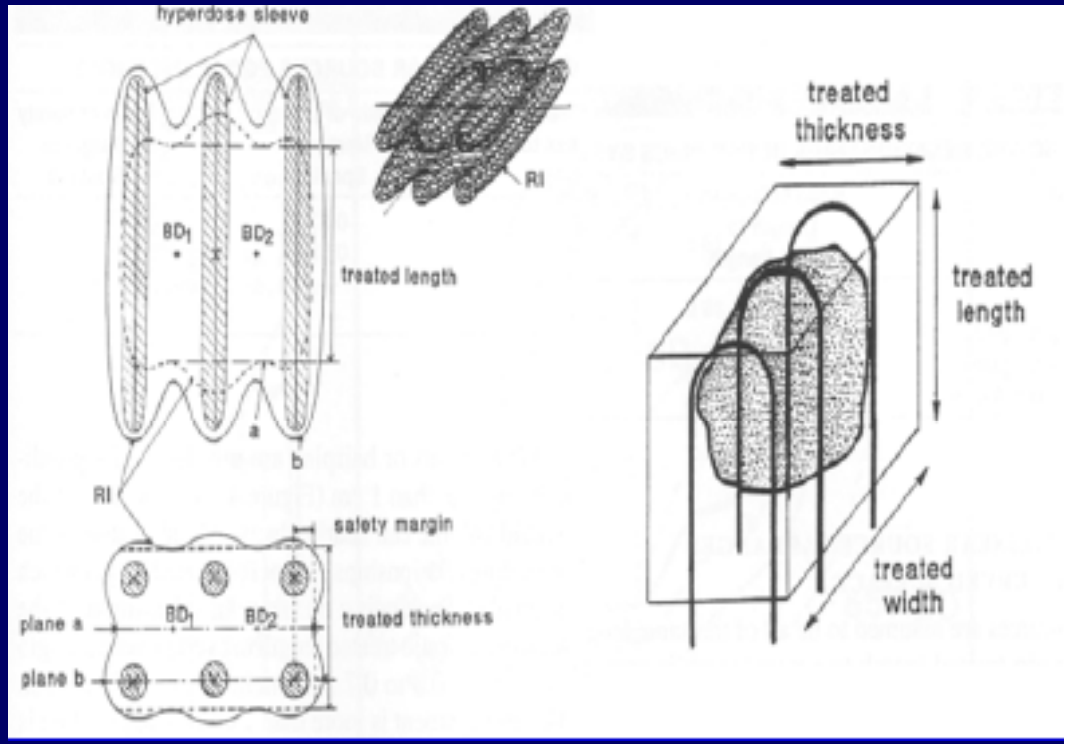
Paris system for Ir-192 hairpins or looping catheters most applicable to H&N brachytherapy

Standard Paris system limits hotspots by using no larger than 1.2 cm catheter spacing

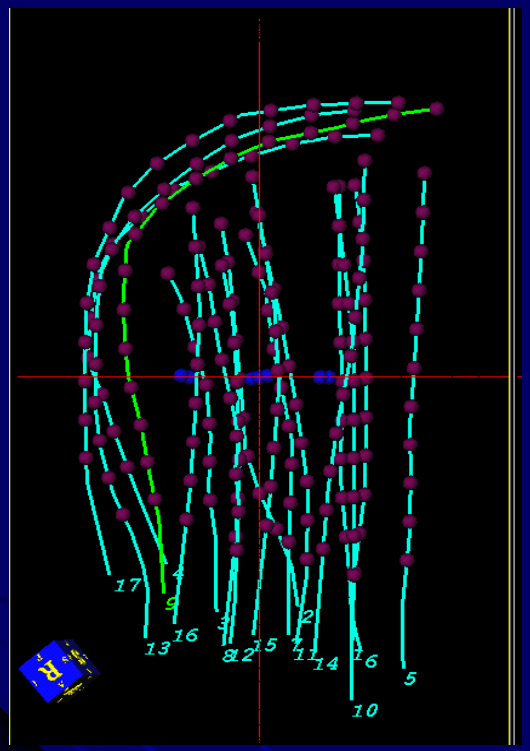
Catheter spacing larger than 1.4 cm has been shown to increase complications

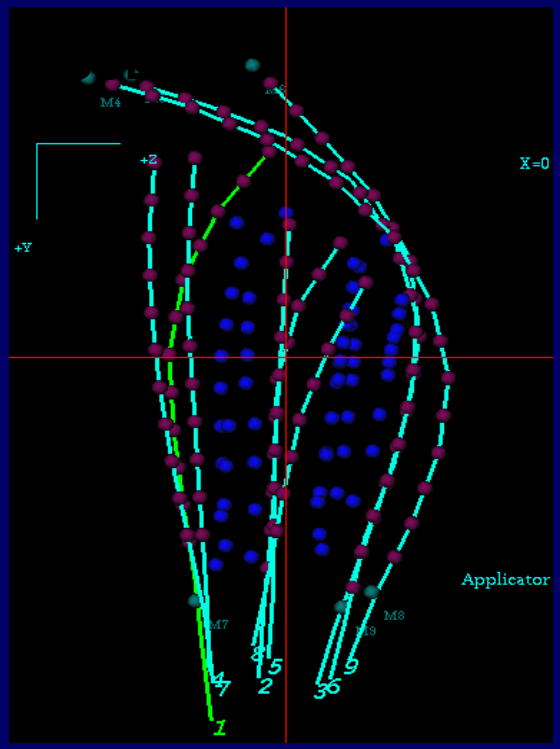
Paris system for Loop technique

- Treated Length = 0.8 x active length
- Treated thickness =1.55 x leg spacing of hairpins
- Treated width = Distance between distal-most hairpins + 0.5 x leg spacing of hairpins



SSDS





- More homogeneous dose distribution in SSDS

- Hotspot will be in the center of the implant in Paris while at the periphery in SSDS

  clinical relevance? (homogeneity is brachytherapy's advantage!!)

Head and Neck Implant dosimetry

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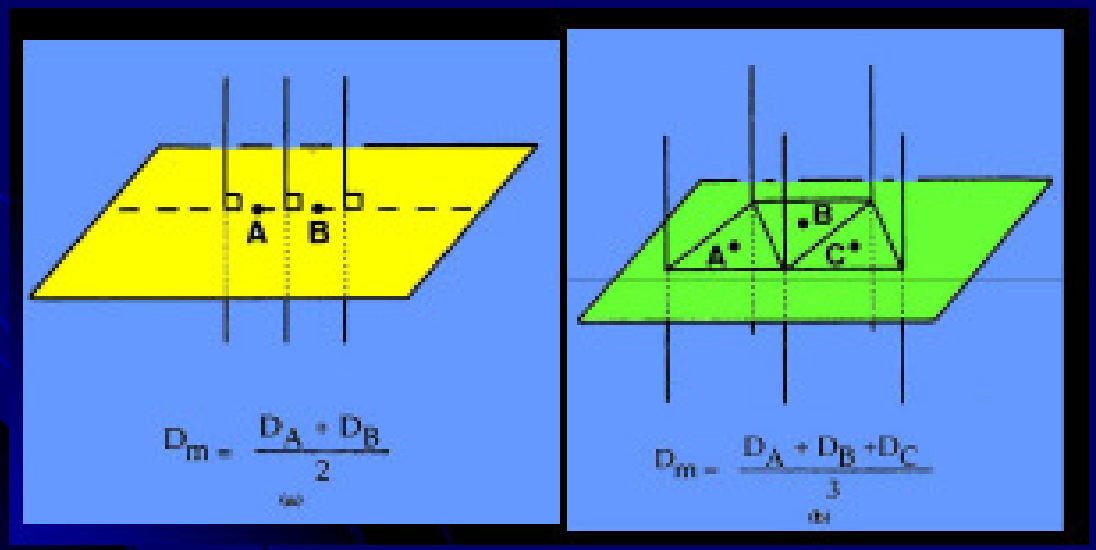
Dose points – rule of thumb

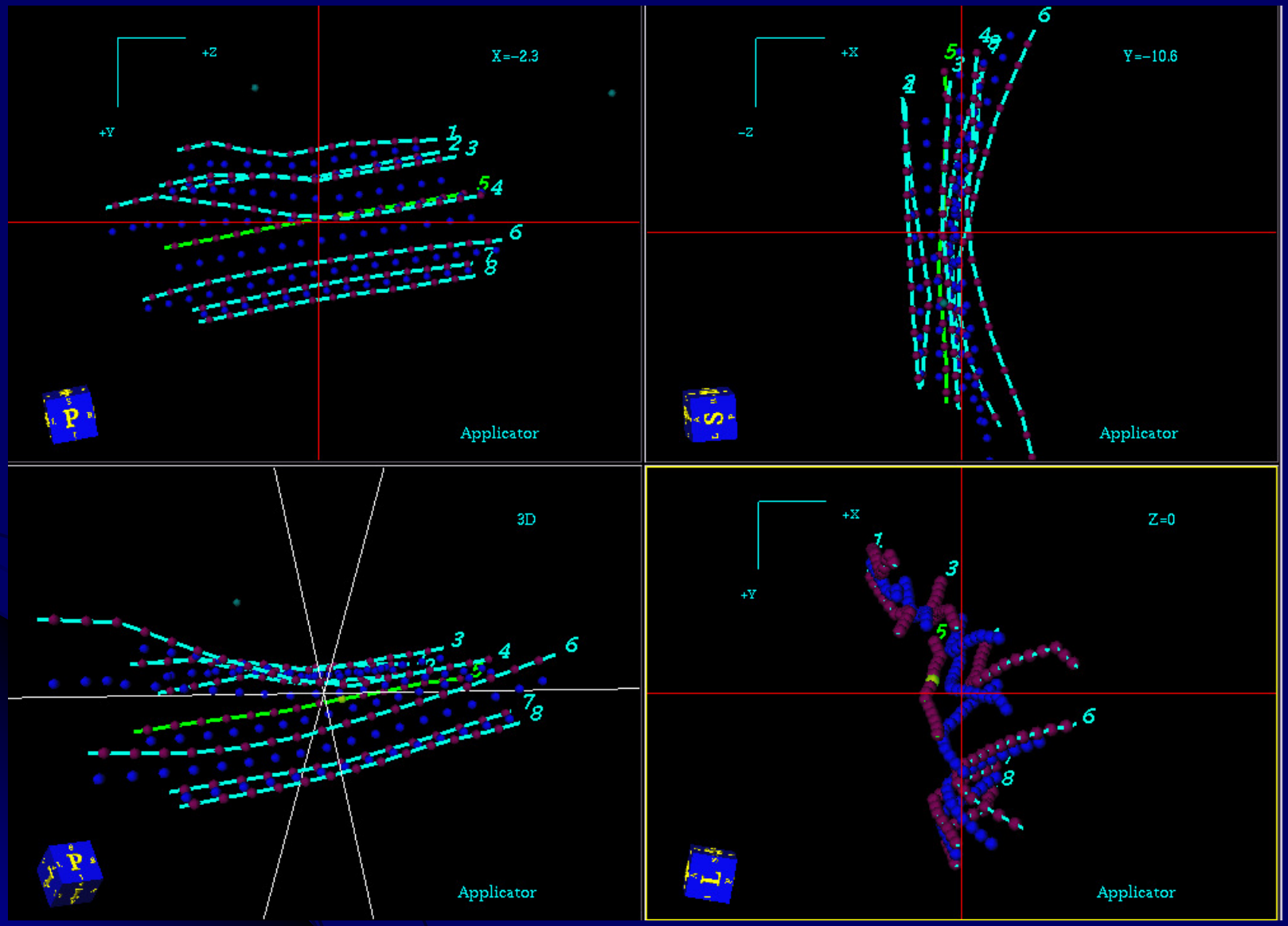
- At the geometric center (triangle, square)
- Should receive the minimum dose



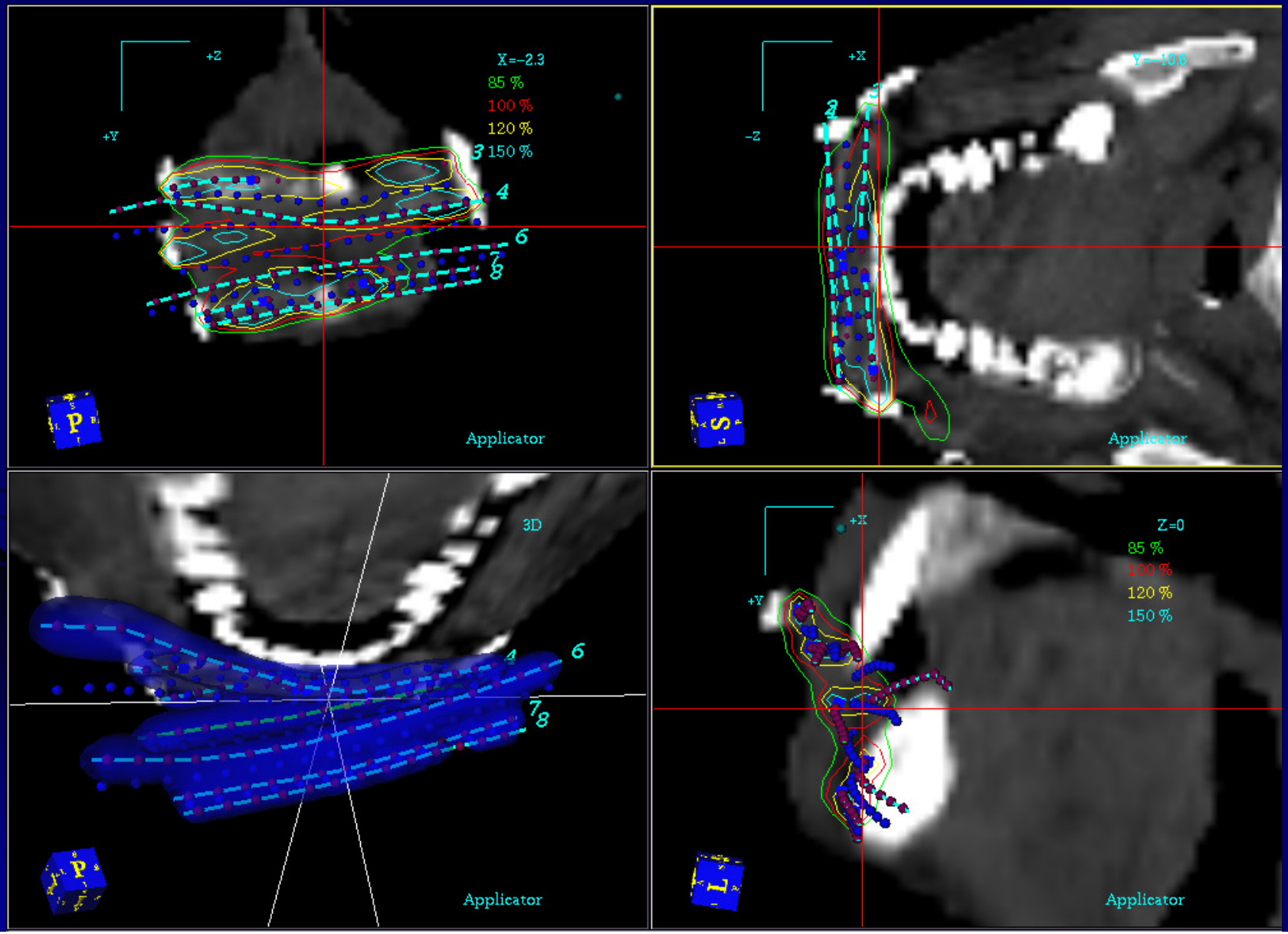
Lip and Buccal mucosa

- Single plane implant, with an inter-catheter spacing of 0.8-1.2cm
- Dose points defined at midway between the catheters where the dose is minimum (basal points)

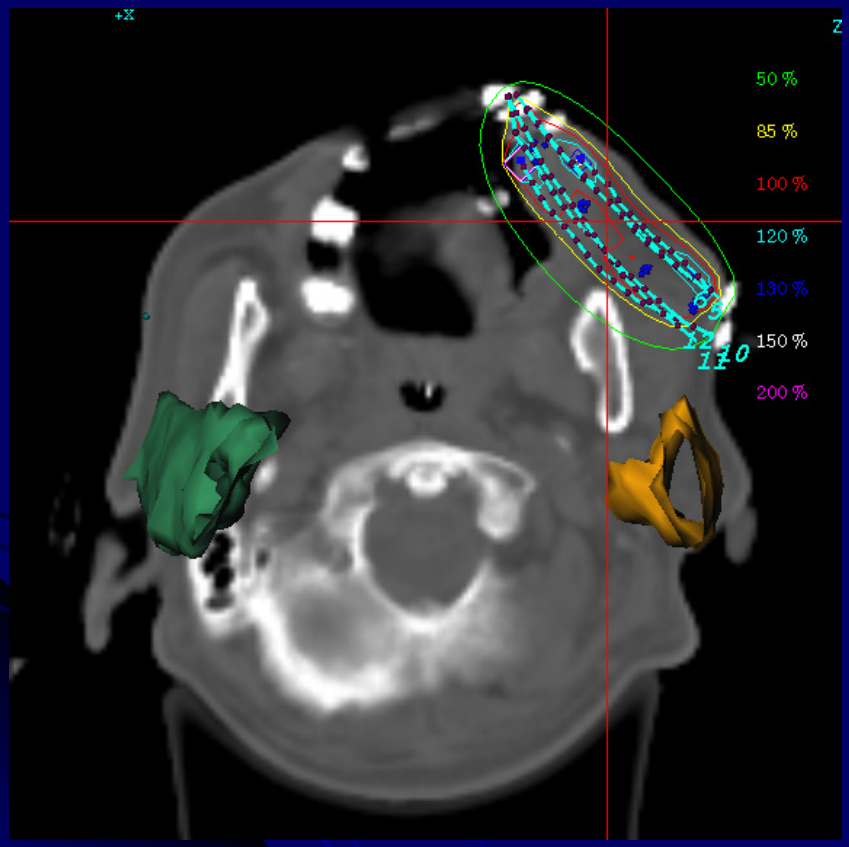
Dose points-Lip implant

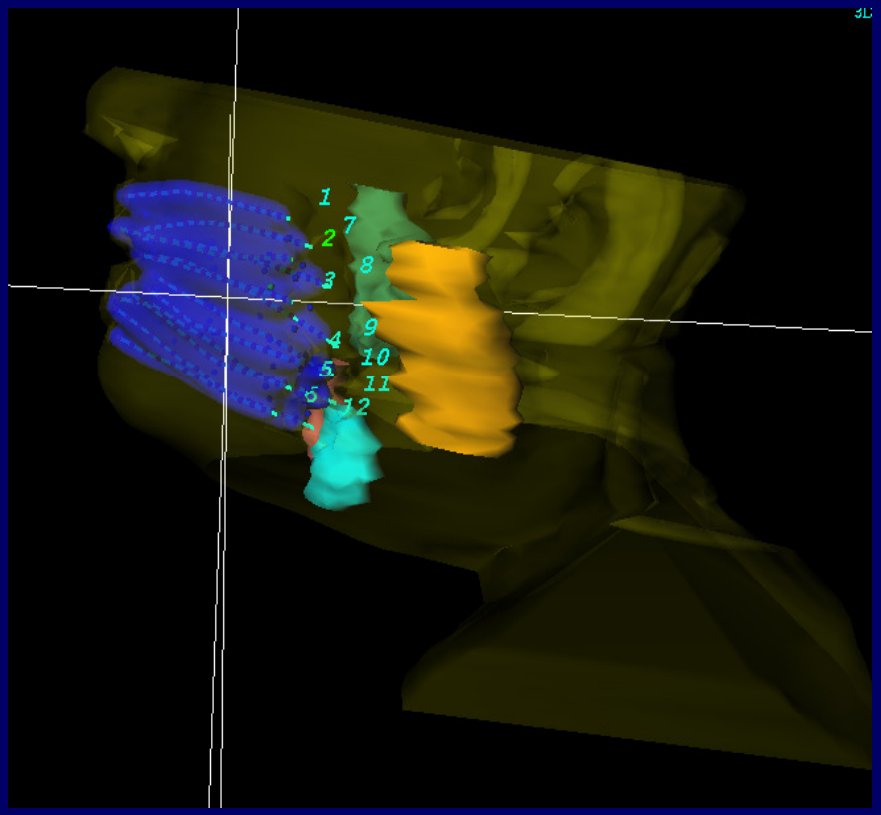


Dose distribution-Lip implant

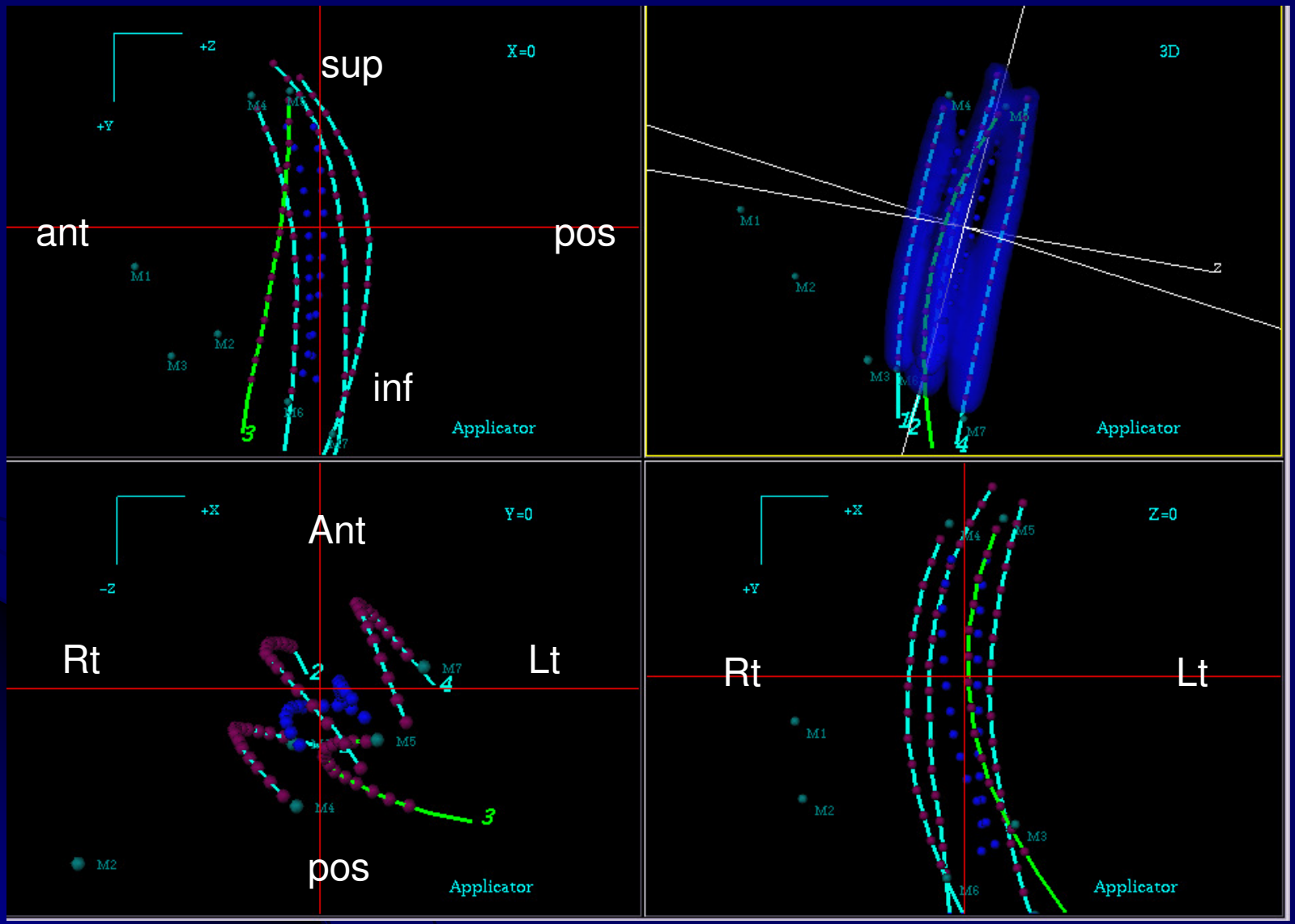


Dose distribution-Buccal Mucosa

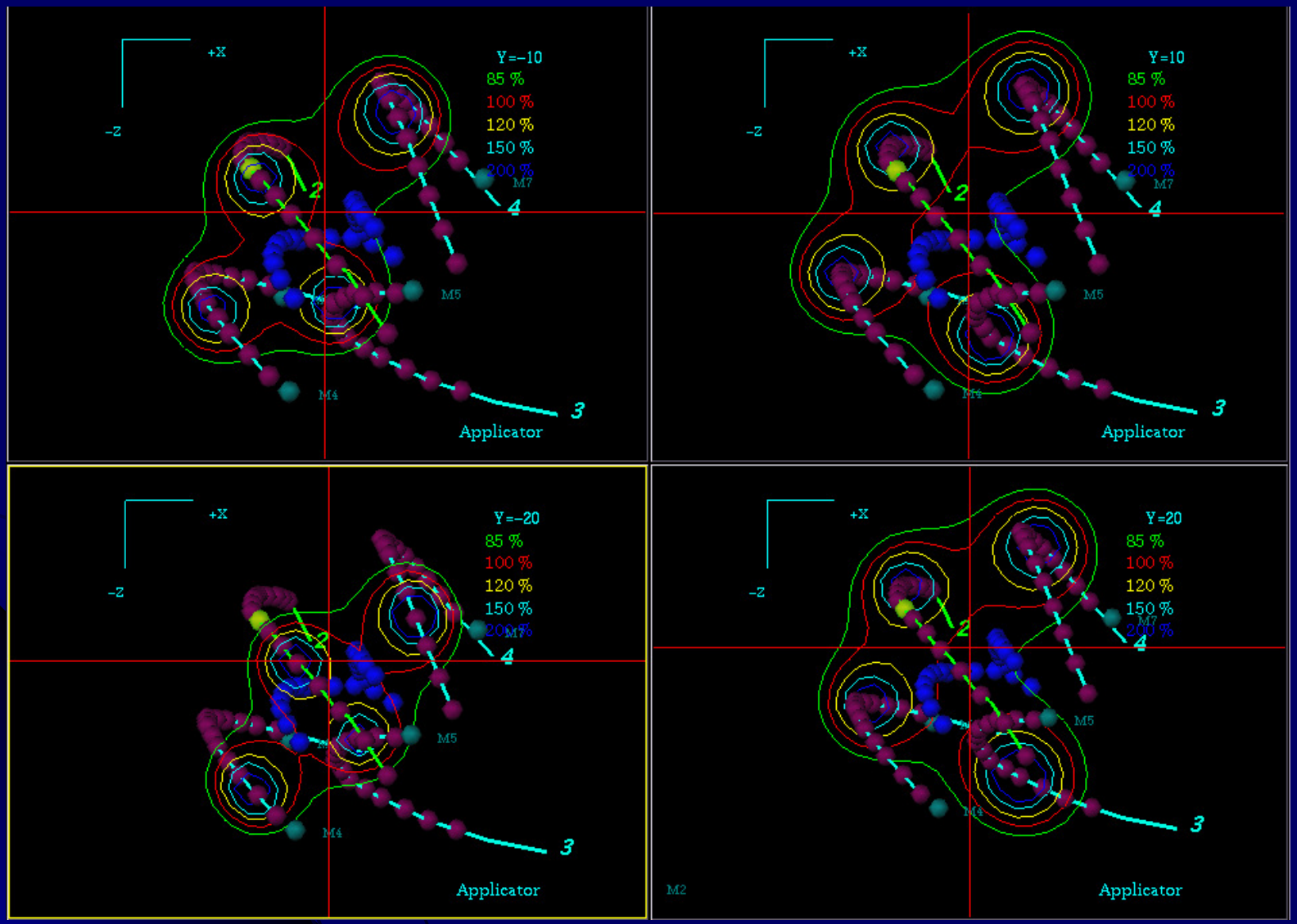




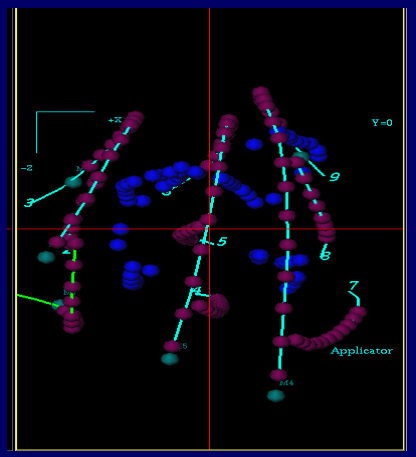
Dose points-tonsil implant

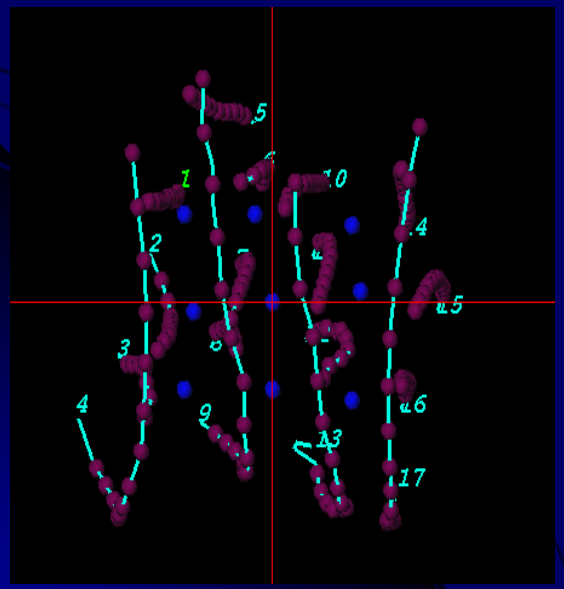


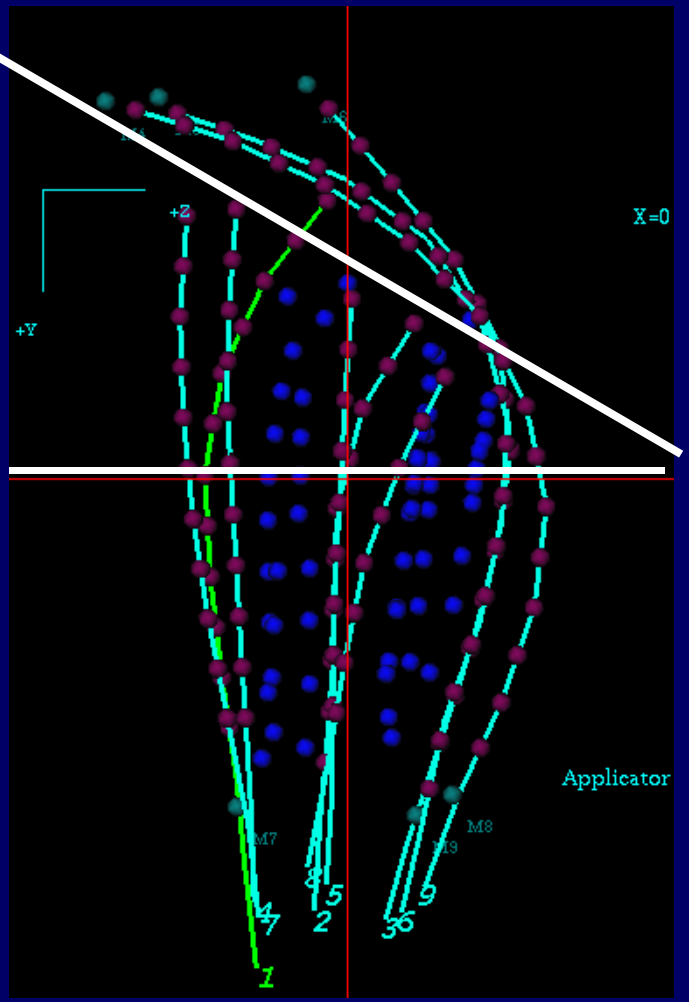
Dose distribution-tonsil implant



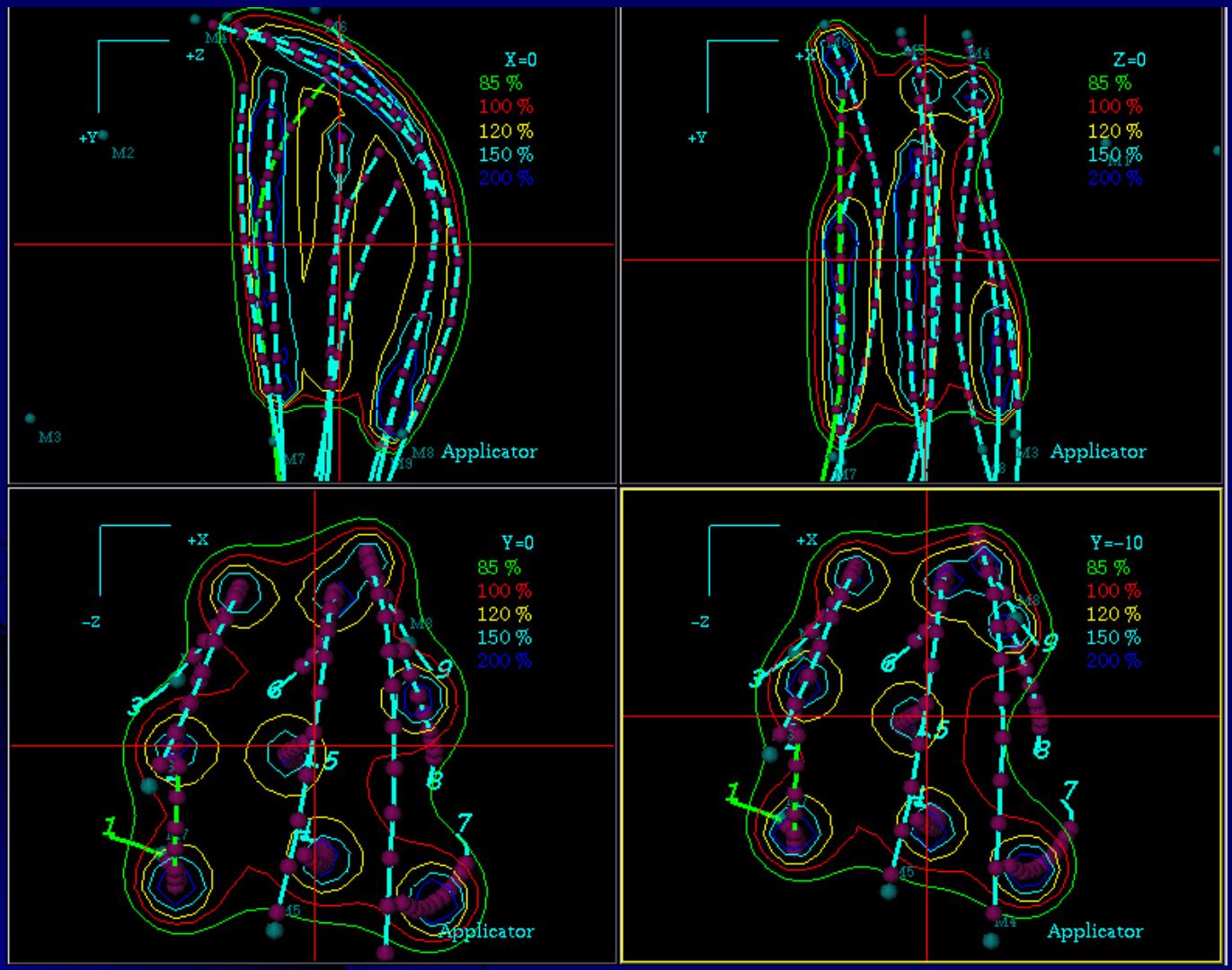
Dose points-Base tongue



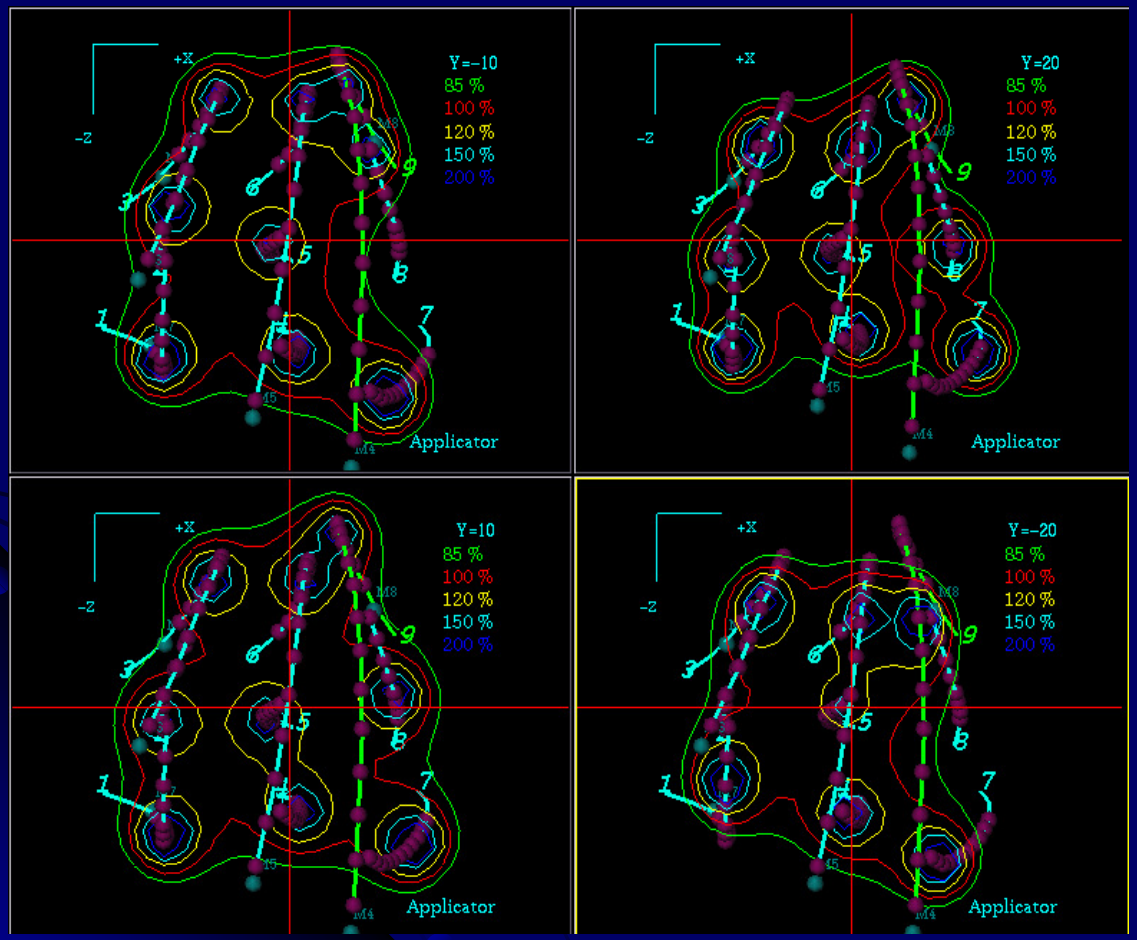


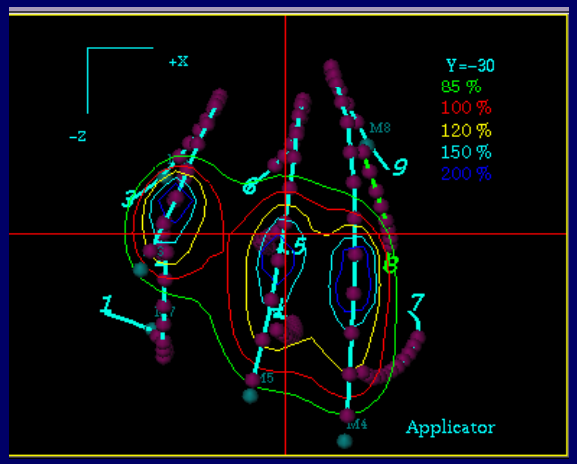


Dose distribution-Base of tongue implant

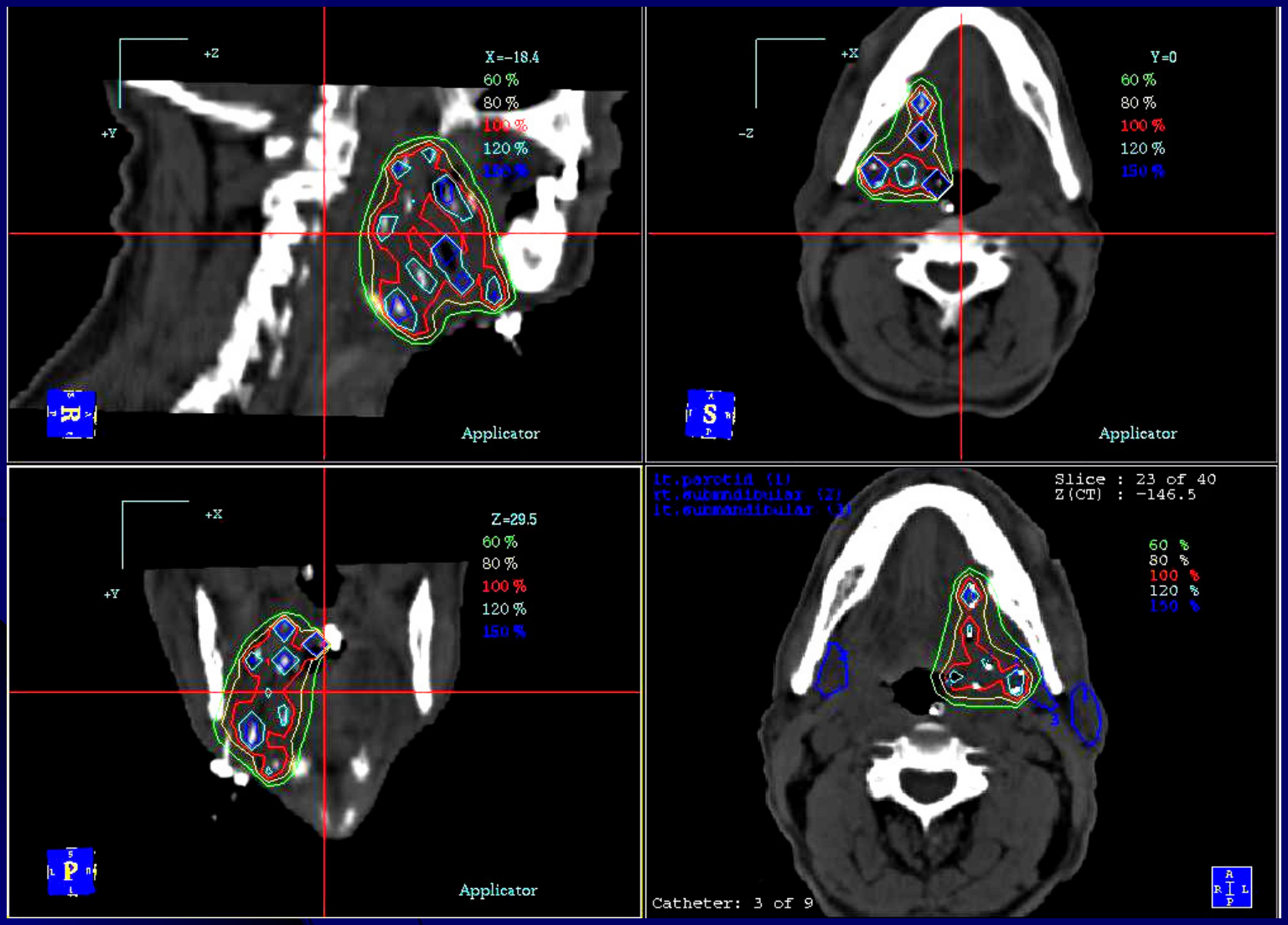


Dose distribution-Base of tongue implant

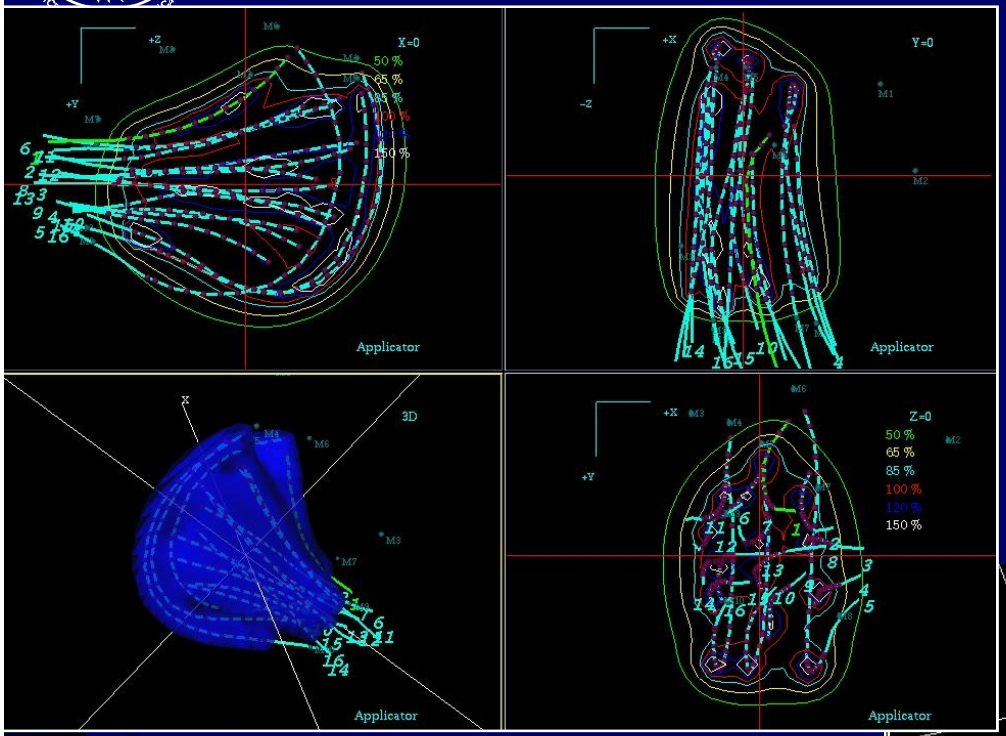




Dose distribution-base of tongue implant – Image based CT plan

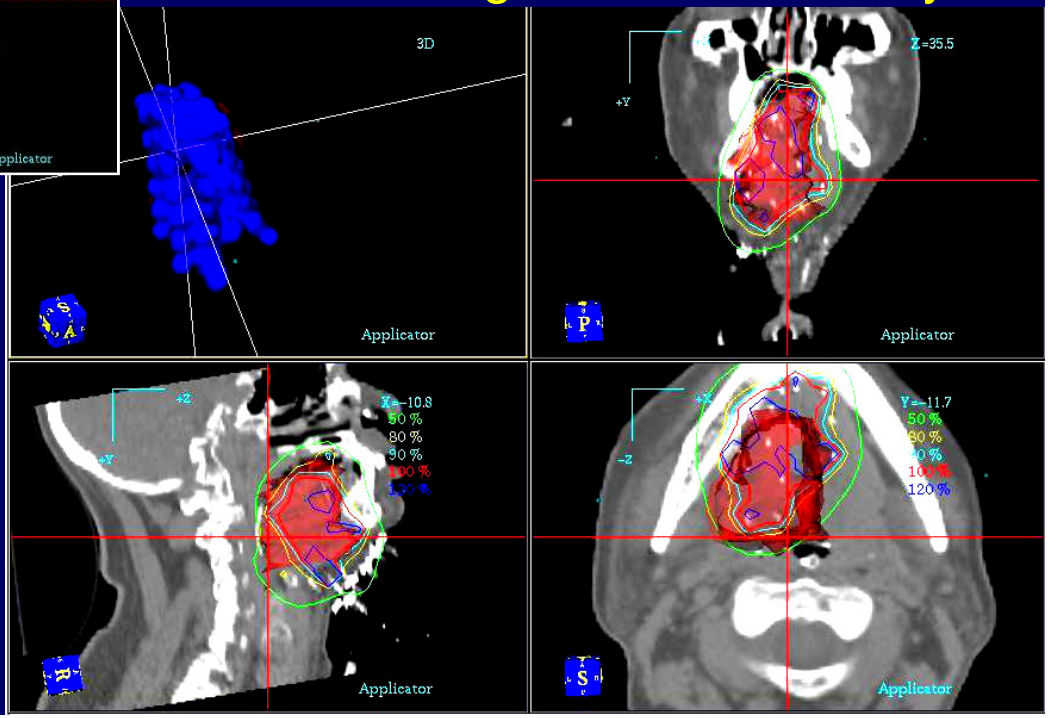


Dose distribution-base tongue

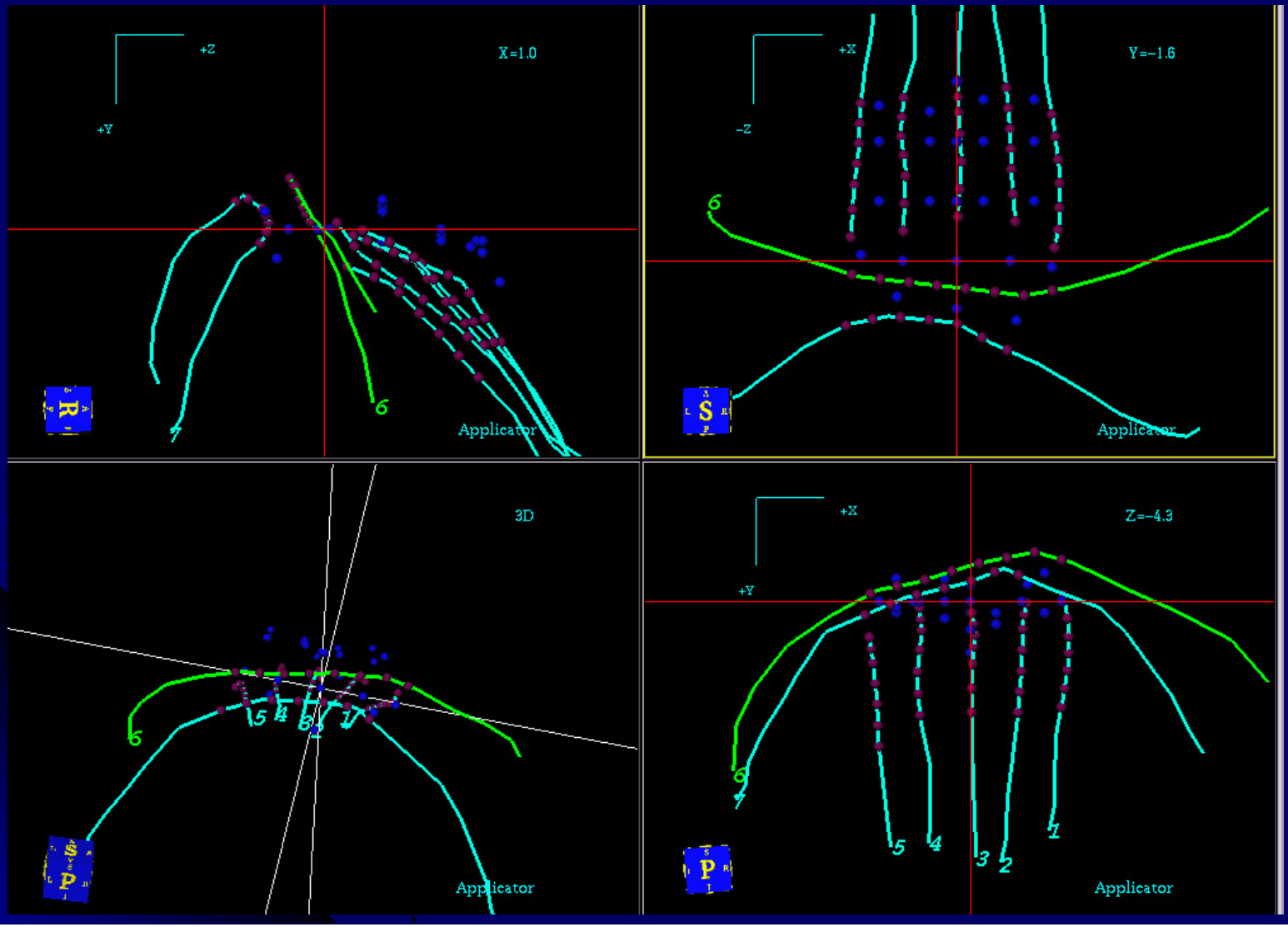


Radiograph based dosimetry

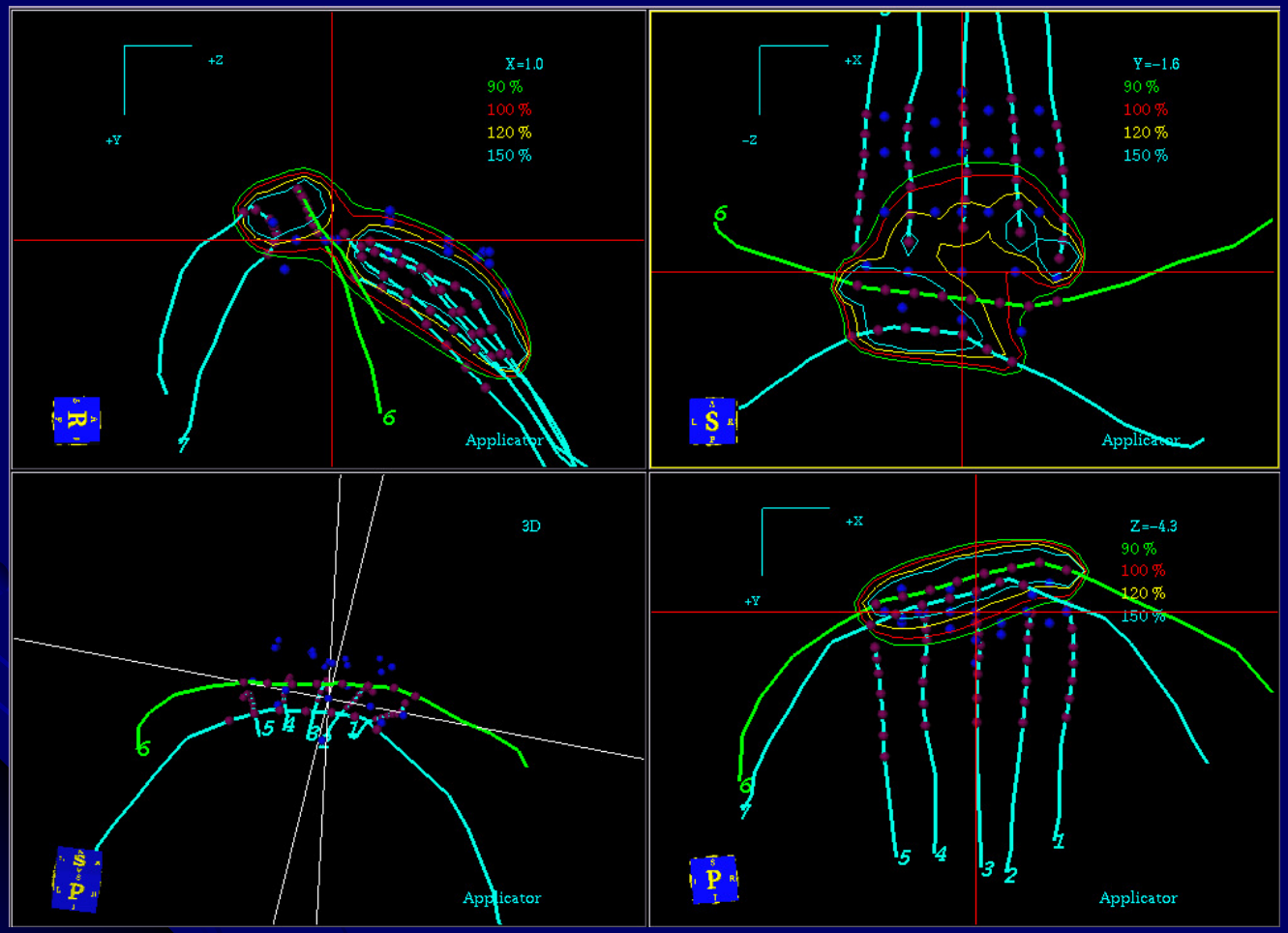
CT image based dosimetry



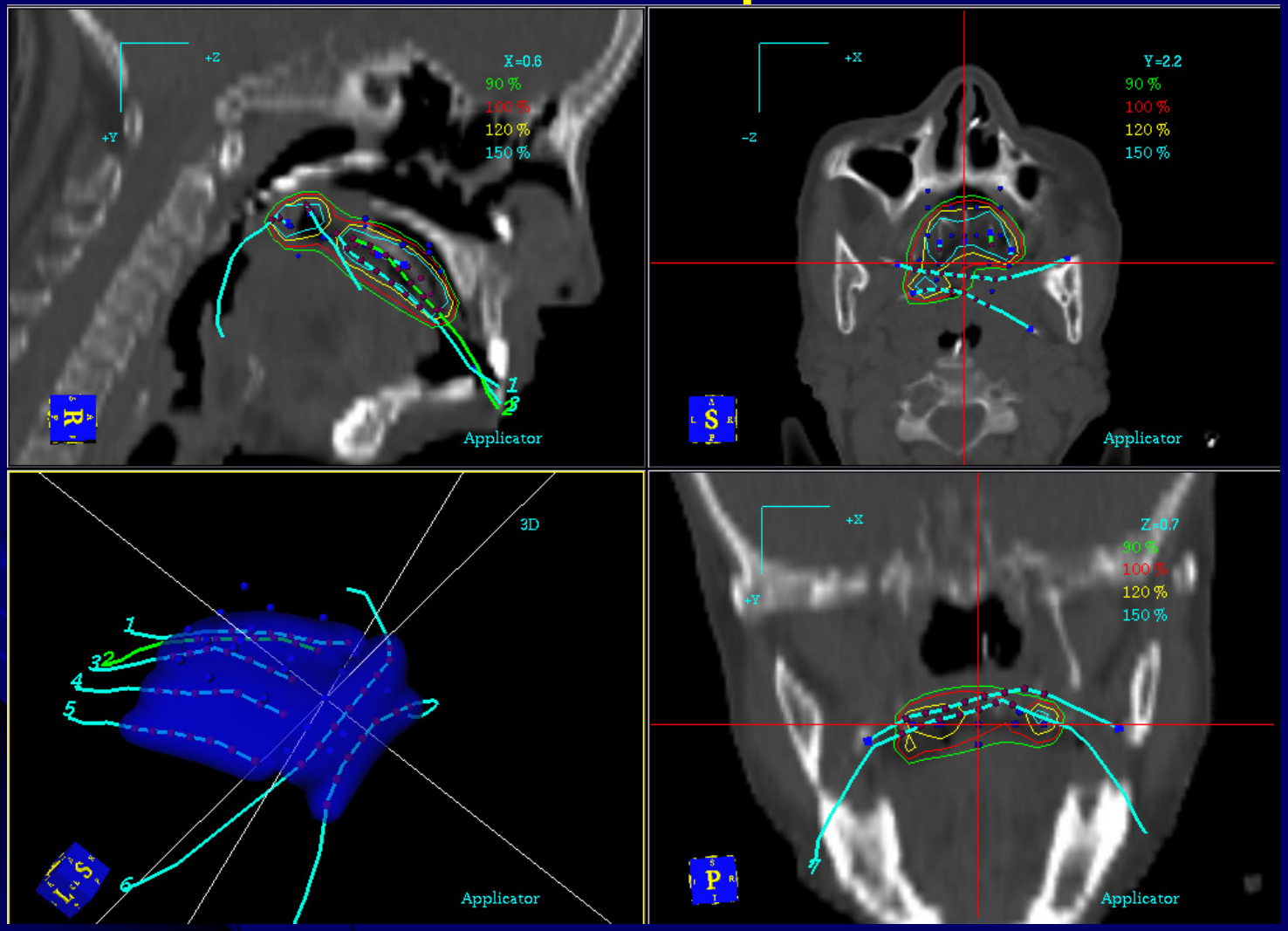
Dose points-Soft and hard pallette implant



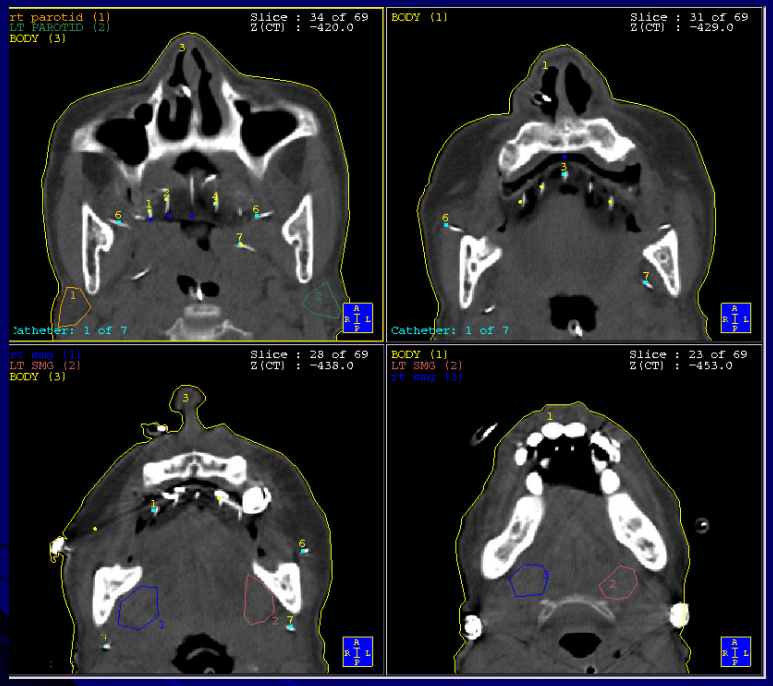
Dose distribution soft and hard palette implant

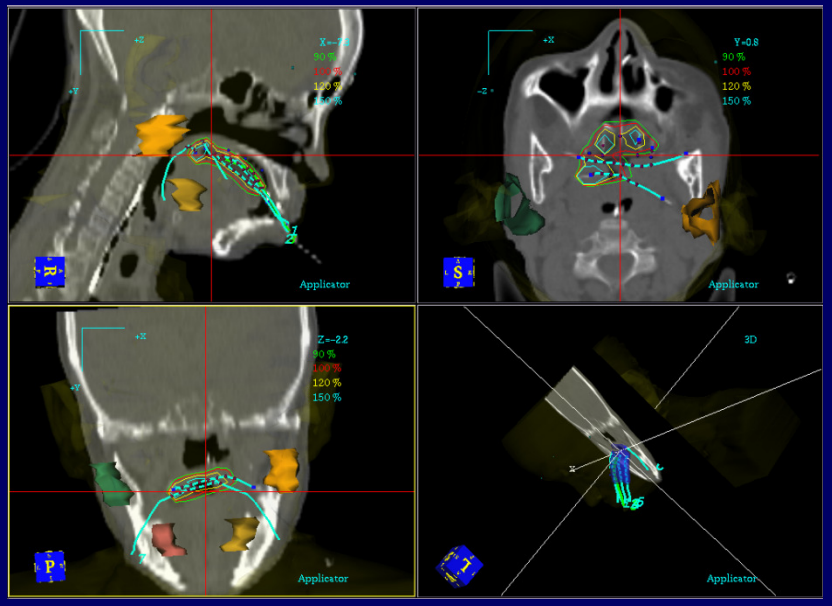


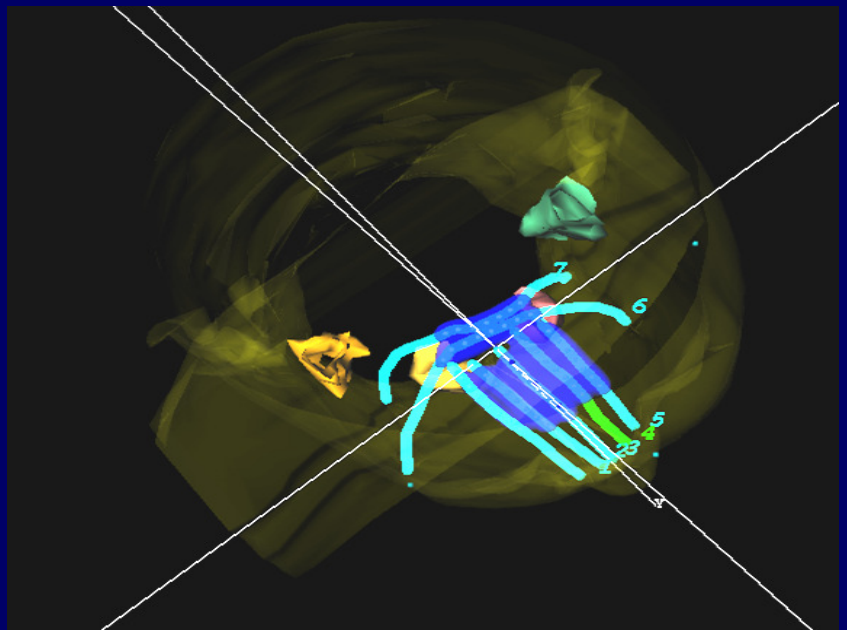
Dose distribution soft and hard palette



Hard palette and soft palette



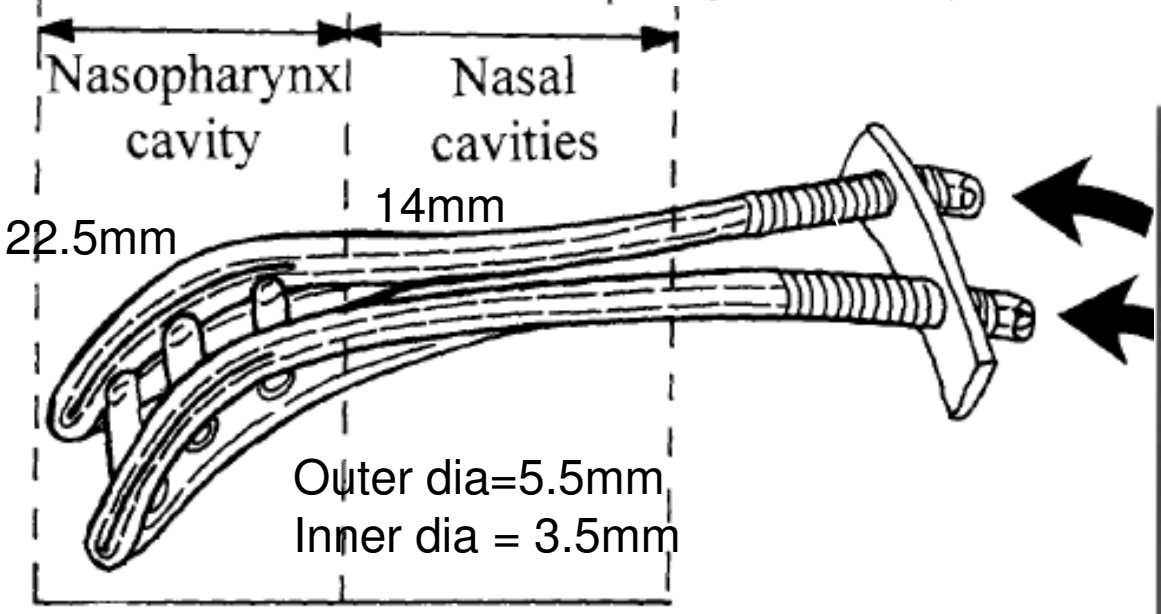




Endocavitary brachytherapy Nasopharynx

A new applicator design for endocavitary brachytherapy of cancer in the nasopharynx

Peter C. Levendag[a,*], Rob Peters[b], Cees A. Meeuwis[c], Leo L. Visch[b], Dick Sipkema[a], Connie de Pan[a], Paul I.M. Schmitz[d]



Levendag et al Radiother Oncol 1997

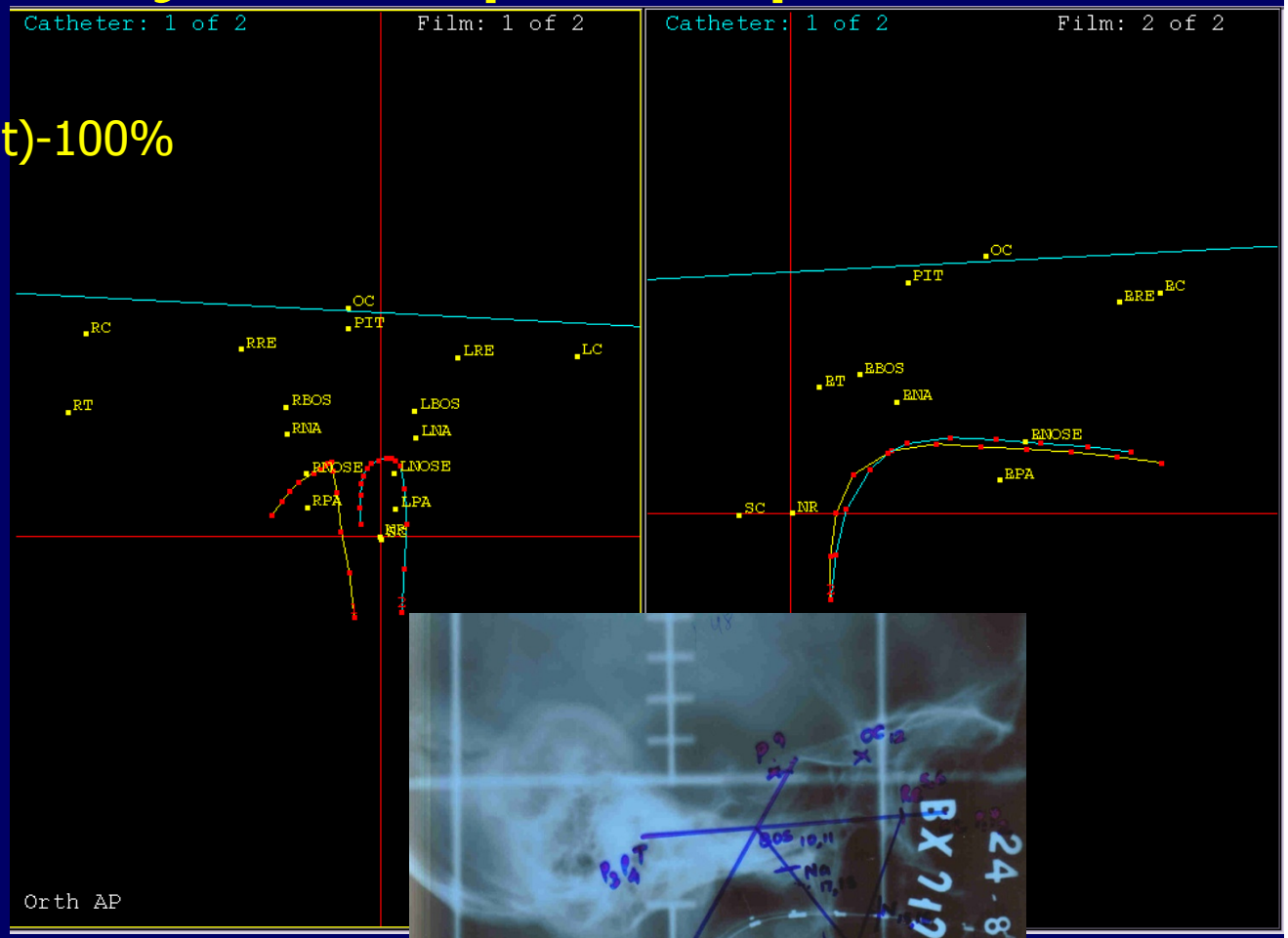
Target volume-Nasopharynx

Treatment Planning

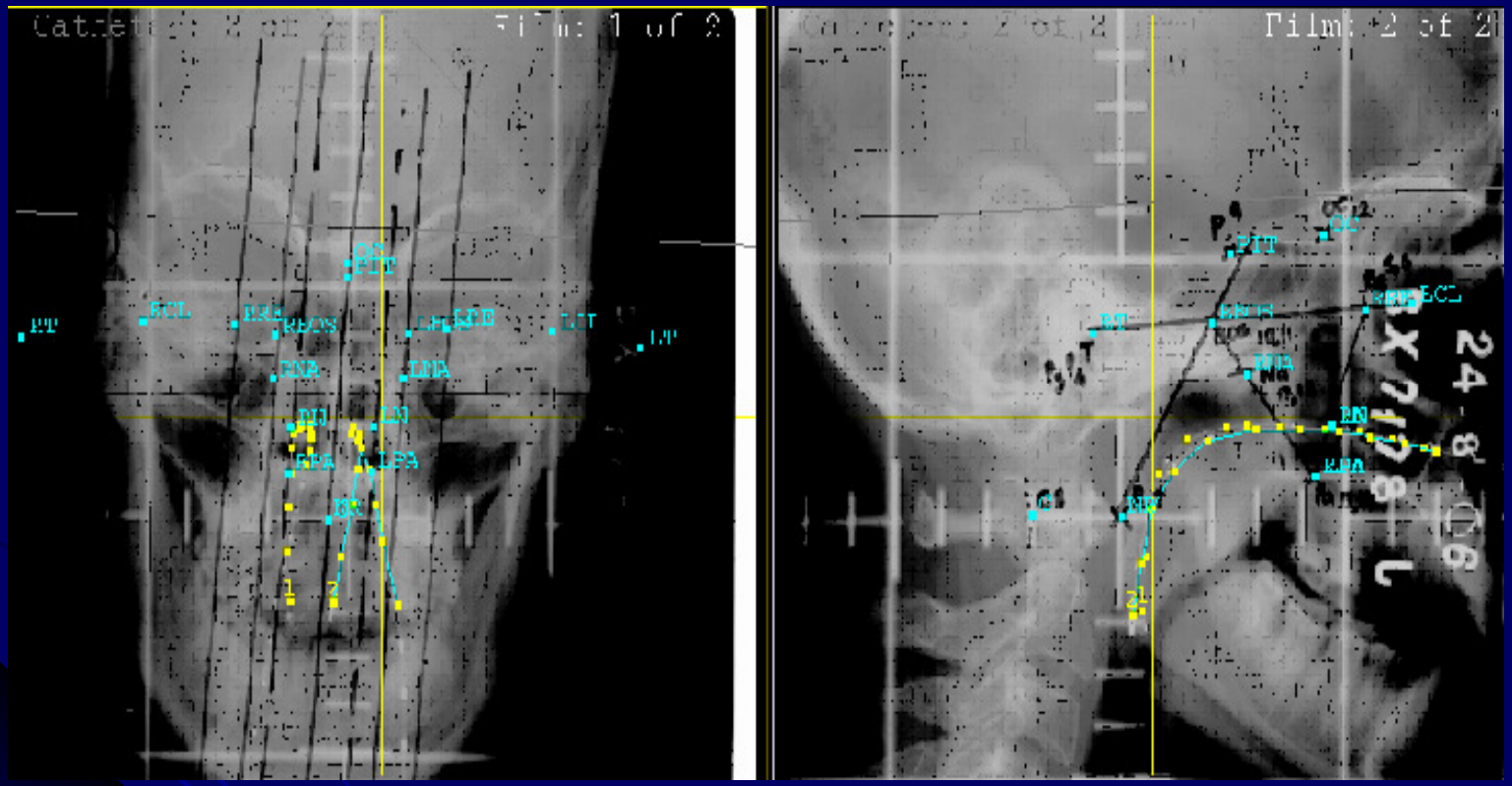
- Treatment planning based on orthogonal radiographs
- target and critical structures are depicted on lateral and AP radiographs.
- Optimise dose distribution such that Target receives a dose of 3Gy(reference dose) Normal tissue points receive a dose as low as reasonably achievable
- Dose prescription at 0.75-1cm from the source axis

Nasopharynx implant-points

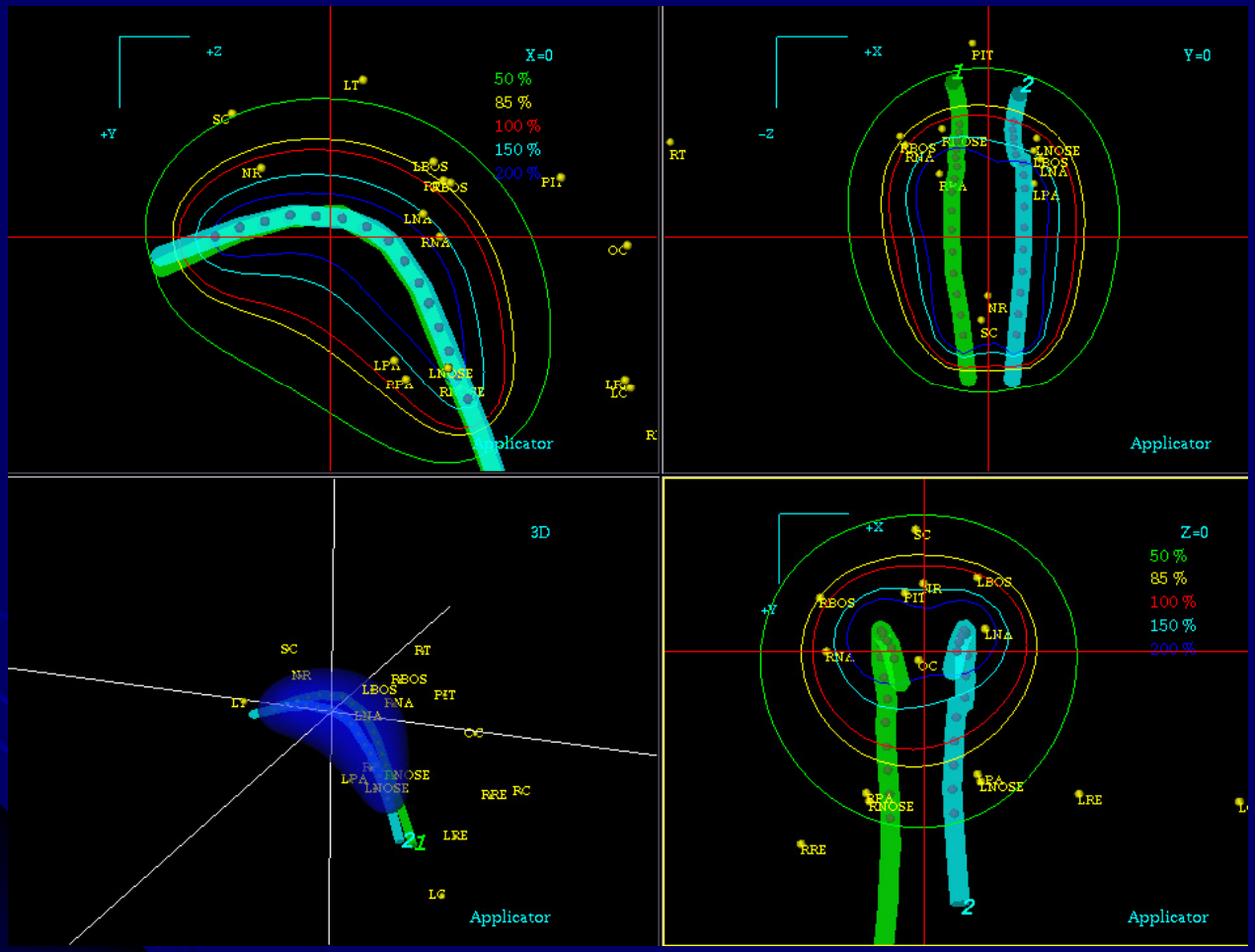
- Nasopharynx point (Rt, lt)-100%
- Nose
- Rouviere's node
- Palate
- Retina
- Pituitary
- Spinal cord
- Optic chiasm
- Pituitary glands



Dosimetry of Nasopharynx



Nasopharynx implant



Head and Neck Implant dosimetry

- Imaging
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Optimization

Design a distribution of source such that the resultant dose distribution satisfies certain constraints and meets certain objectives

Free variables

- Source locations
- dwell times

rule of thumb

Maximise the target coverage

Minimize the dose to the OARs

accumulation of hotspot

Express as a minimization problem

- Minimize the variance of the doses D_i at points *i* on the PTV surface from the prescription dose D_p

$$\text{Minimize } f = \sum (D_i - D_p)^2$$

- *f* is a simple *objective function*

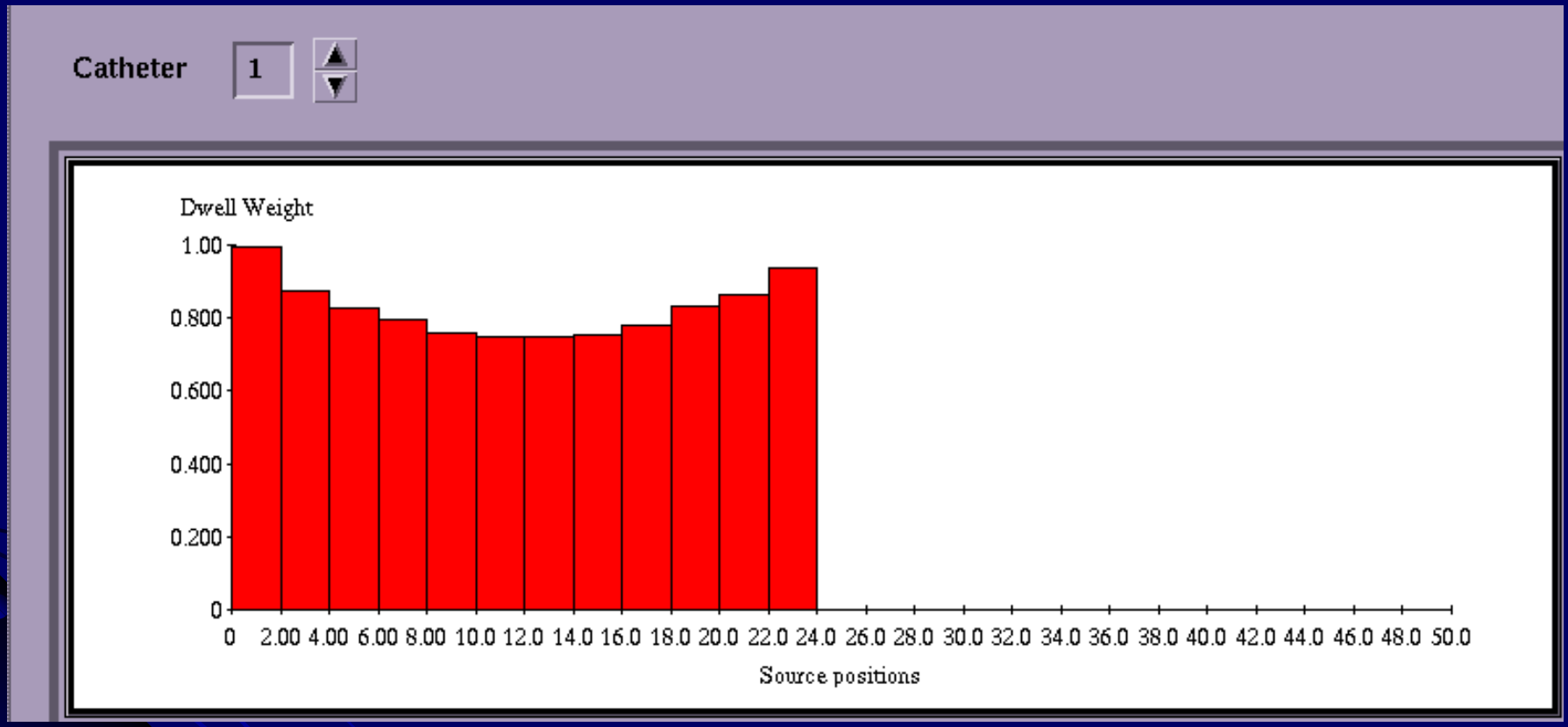
Optimization

- Geometric optimization
- Dose point optimization
- Graphical Optimization
- Inverse optimization
  - Optimization on distance (single plane implants)
  - Optimization on volume (volume implants)

Geometric optimization

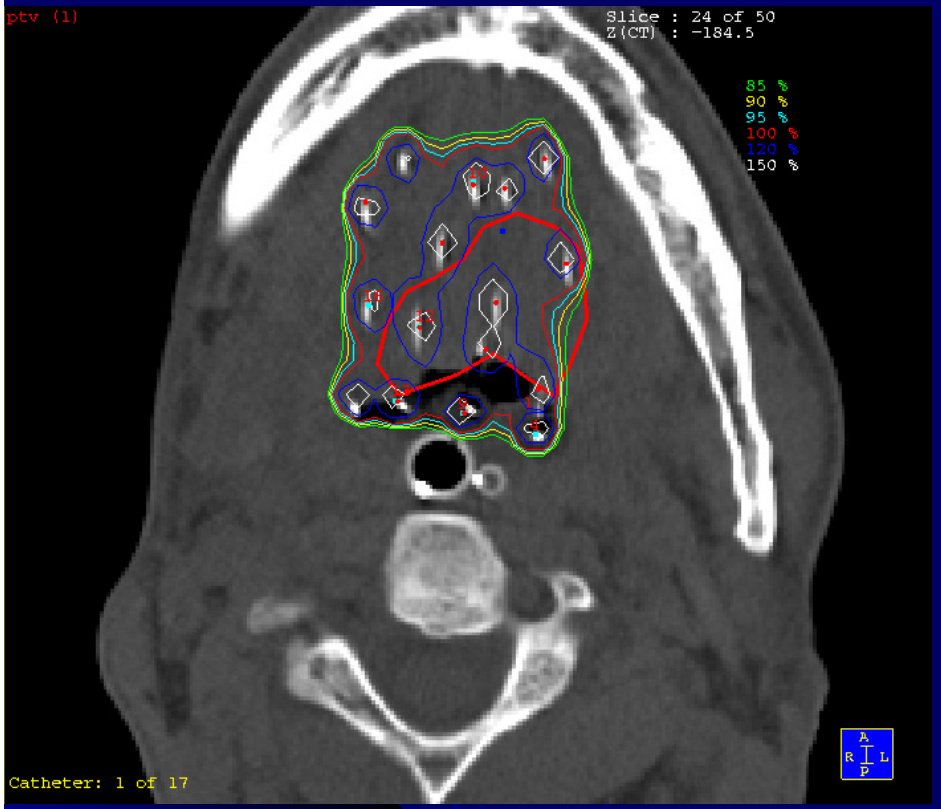
- Heuristic method developed by Edmundson(1993) for HDR dwell times
- Dwell positions are assumed as dose points
- Assume that sources are distributed throughout the implanted volume
- Achieves dose uniformity between the sources

Graphical Optimization

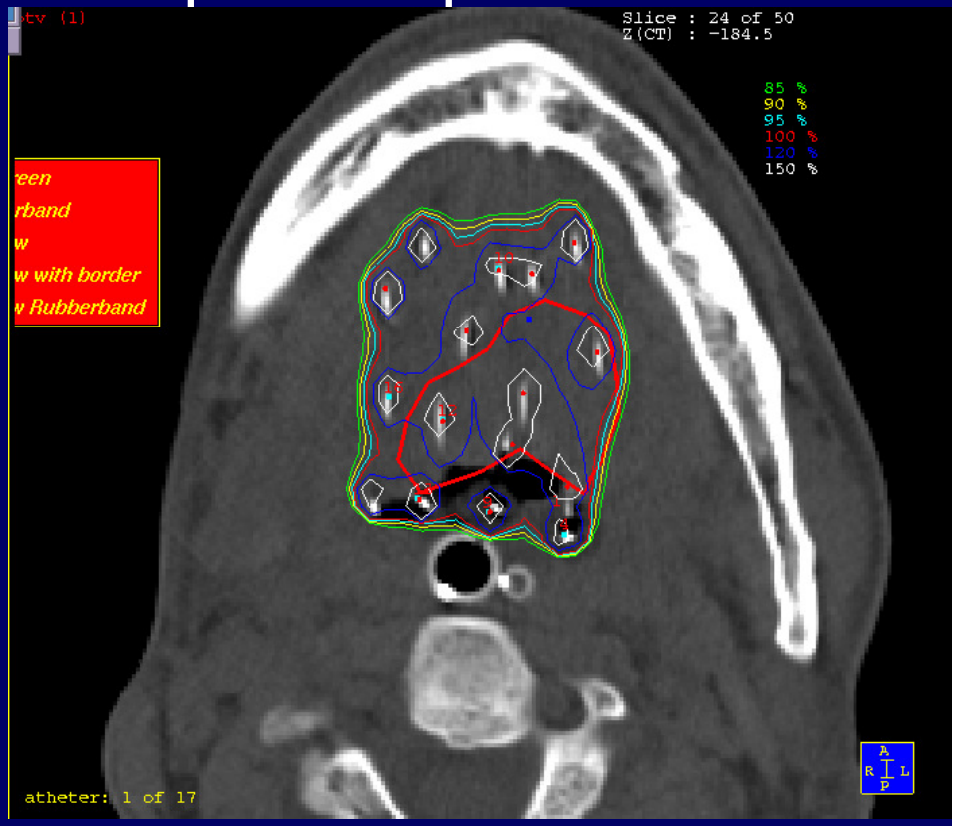


Manipulation of dwell time/weights to improve the target coverage, minimize the dose to OARs without compromising the quality of the implant

Geometric optimization



Graphical optimzation



Should be used with caution
May result in a unacceptable distribution

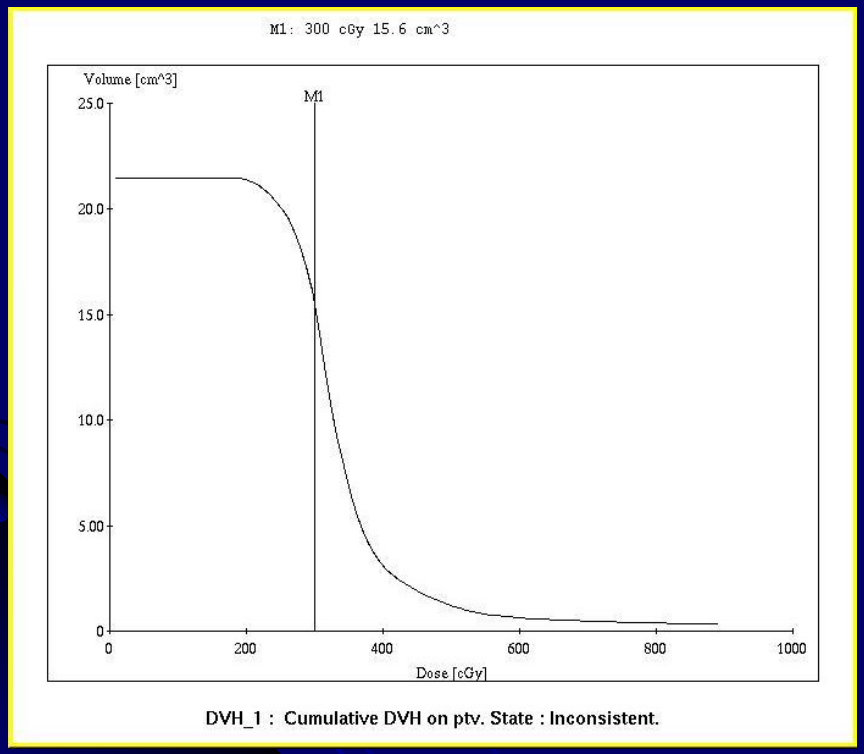
Head and Neck Implant dosimetry

- Imaging
- Reconstruction & Source Activation
- Dosimetry systems
- Definition of dose points-prescription
- Optimization
- Evaluation

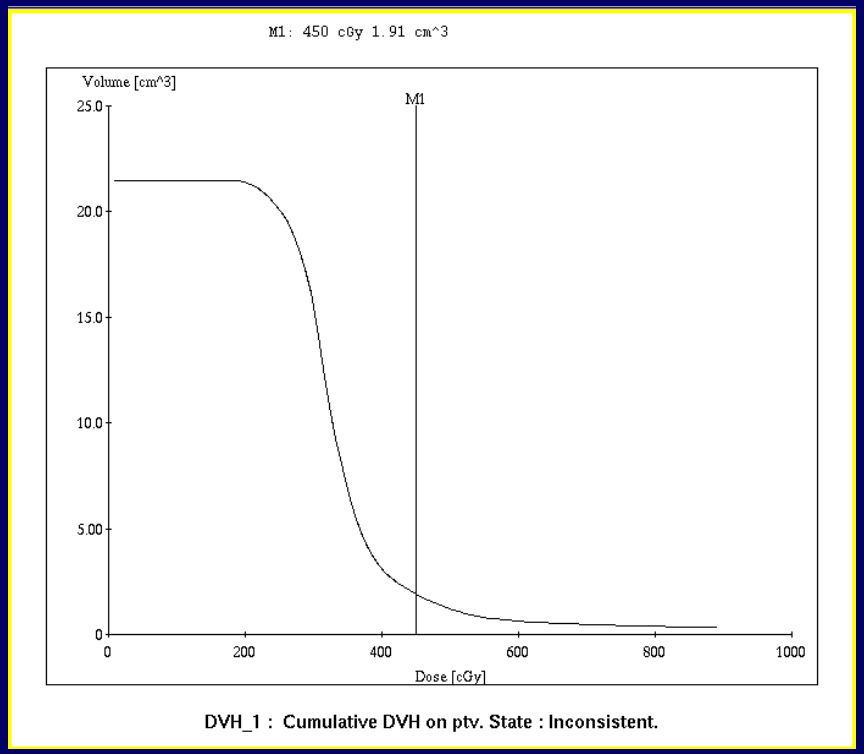
Evaluation

- Target coverage
- Prescription isodose line (85-110%)
- DHI (Volume covering 150% isodose)
  - >0.7 is acceptable
- Volume of 2* BDR
  - Not the absolute volume
  - Spatial distribution (figure)

Dose Volume Histogram

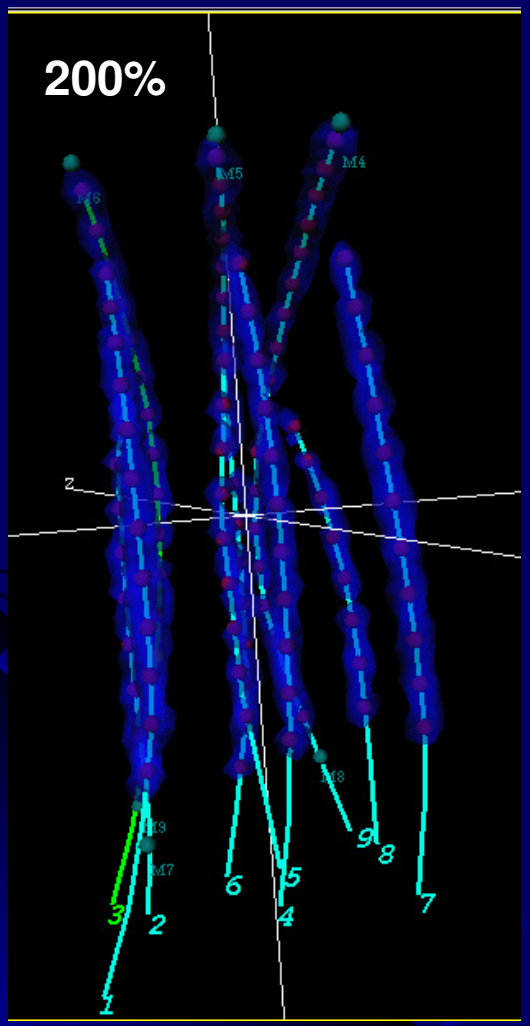


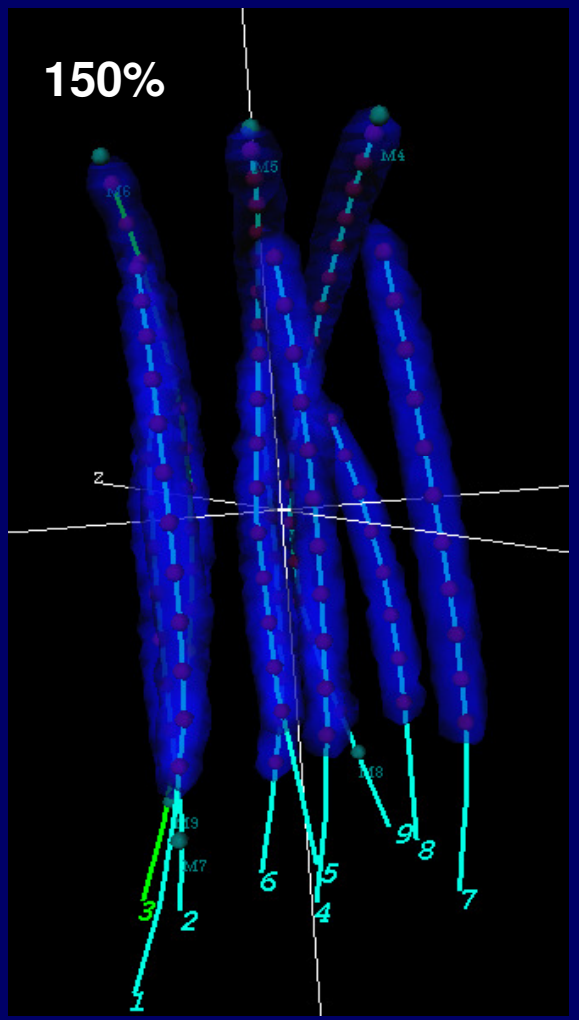
DVH_1 : Cumulative DVH on ptv. State : Inconsistent.

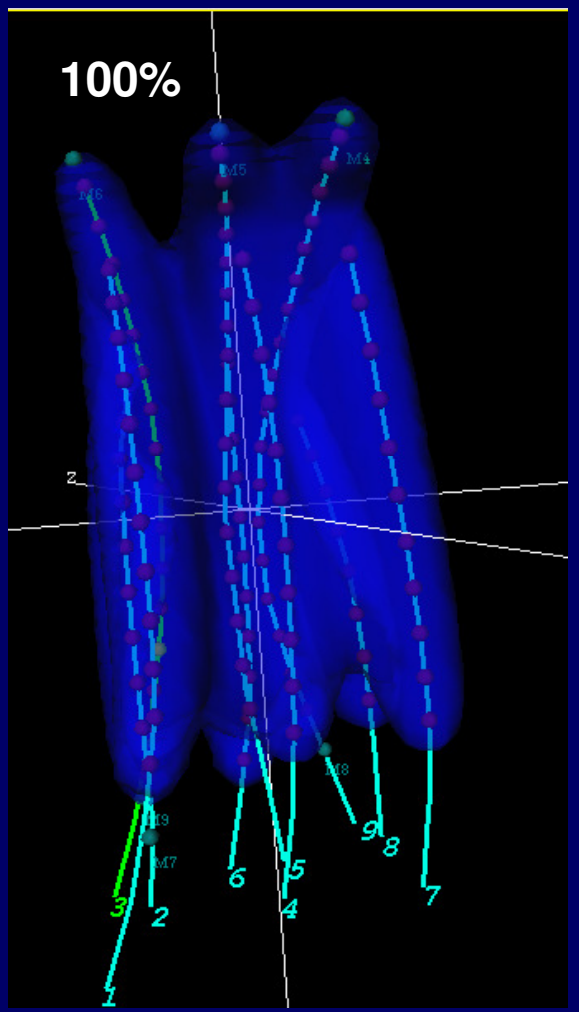


DVH_1 : Cumulative DVH on ptv. State : Inconsistent.

Volumes of high dose regions







Summary

- Reconstruction should be accurate, precision in planning is mandatory
- Geometry of the implant is the key, respect the rules of dosimetry systems
- Optimization may correct for small geometrical irregularities
- Graphical optimization should be used with caution especially in H&N Brachytherapy
- CT/MR Imaging provides better anatomical information, hence better dosimetry
- Time tested technique with good results, cannot be equaled even by modern techniques such as IMRT,IGRT.

Thank you

Questions?