# SBRT Treatment Planning: Practical Considerations

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I have no conflicts of interest to disclose.

# Outlines

- The Basic Principles of SBRT Treatment Planning
  - Conventional fractionated plan vs. SBRT plan
  - Cranial SRS plan vs. SBRT plan
- Practical Considerations on SBRT Treatment Planning
  - Spine
  - Lung
  - Liver
- Lessons learned from our experiences

# Stereotactic Body Radiation Therapy (SBRT)

- Fractional dose $\geq$5Gy

  range: 5 Gy to 34 Gy per fraction
- Number of fractions $\leq$5

  range: 1 to 5
- Safe delivery is of utmost importance due to high fractional dose and small number of fractions.

# Montefiore-Einstein SBRT Experiences

- Started 1st SBRT Spine 1/2008
- Started 1st SBRT Lung 4/2008
- Started 1st SBRT Liver 8/2008
- About 2 new SBRT cases weekly ever since
- Machines Varian Trilogy or Truebeam
- Eclipse TPS

# Montefiore-Einstein Cancer Center (MECC) SBRT Registry

**Spine**

*1-3 lesions*

- Single Fraction: 16 Gy
- Three Fraction: 24 Gy (8 Gy per fraction)

**Lung**

*Peripheral Lesions*

- Three fractions: 60 Gy (20 Gy per fraction)

*Central Lesions*

- Five fractions: 50 Gy (10 Gy per fraction)

**Liver**

*Metastasis*

- If lesions > 2cm from Porta Hepatis/Bile Duct: Three Fractions 20Gy x 3
- If lesions ≤ 2cm from Porta Hepatis/Bile Duct: Five Fractions 10Gy x 5

*Hepatocellular Carcinoma*

- Five fractions: 30-50 Gy (depends on $V_{eff}$)

# RTOG SBRT Protocols

- 0631 Spine
- 0813 and 0915 Lung
- 0438 Liver

These protocols specify detailed requirements for treatment planning:

Dose Prescription

Target Coverage

Dose Constraints

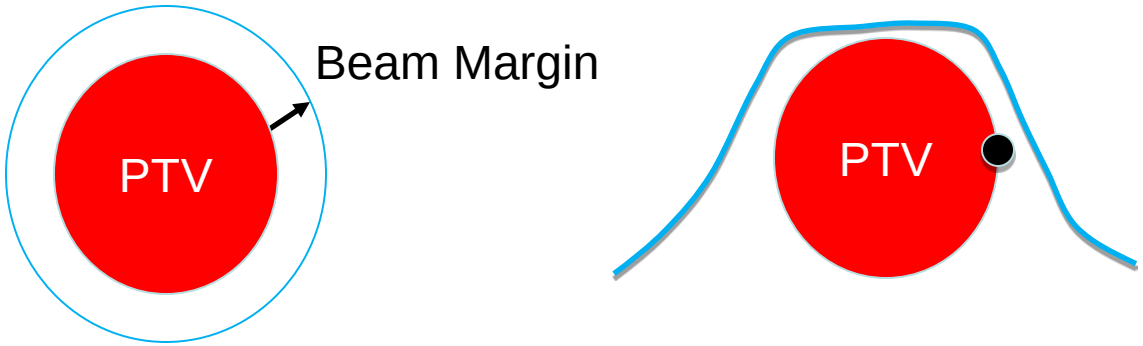
# The Basics of Treatment Planning for SBRT

- The goal of SBRT treatment is to “ablate” tissues within the PTV, these tissues were not considered at risk for complications.

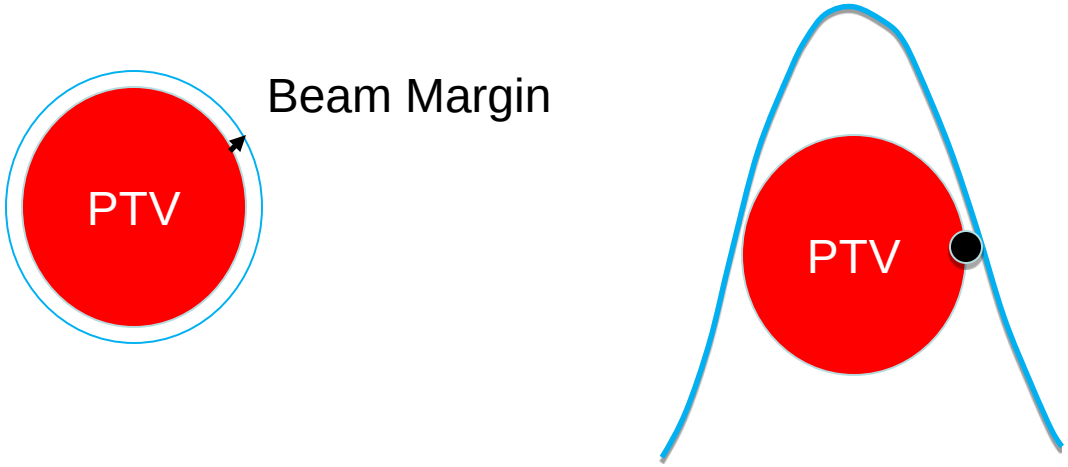
  Dose inhomogeneity inside the PTV was considered acceptable (potentially advantageous) and not considered a priority in plan design.

  Maximum point dose up to 160% of Prescription Dose is common for SBRT plans.
- The main objective of the plan is to minimize the volume of those normal tissues outside PTV receiving high dose per fraction.

If beam margin is close to beam penumbra (5-6 mm)→
Homogeneous PTV dose, Maximum dose about 110% of Prescription Dose (PD).
Dose fall off outside PTV is slow




If beam margin is much less than beam penumbra (0-2 mm) →
Inhomogeneous PTV dose, Maximum dose ~ 125% or more of PD.
Dose fall off outside PTV is fast



# Cranial SRS Planning

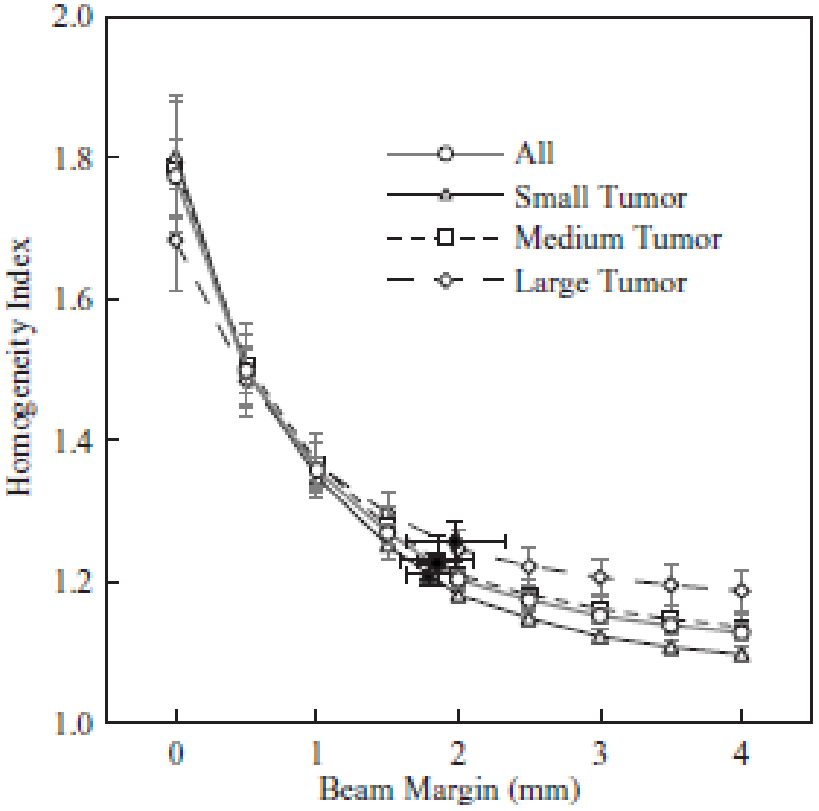



FIG. 1. Homogeneity index (Ratio of Maximum PTV Dose to the PD) vs. beam margin.

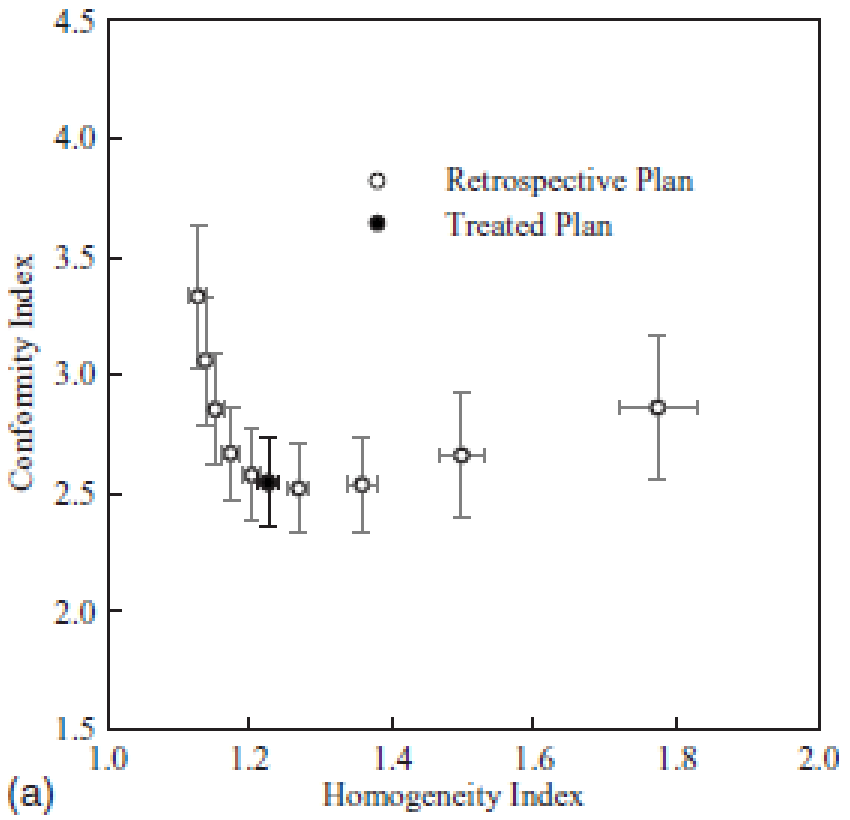
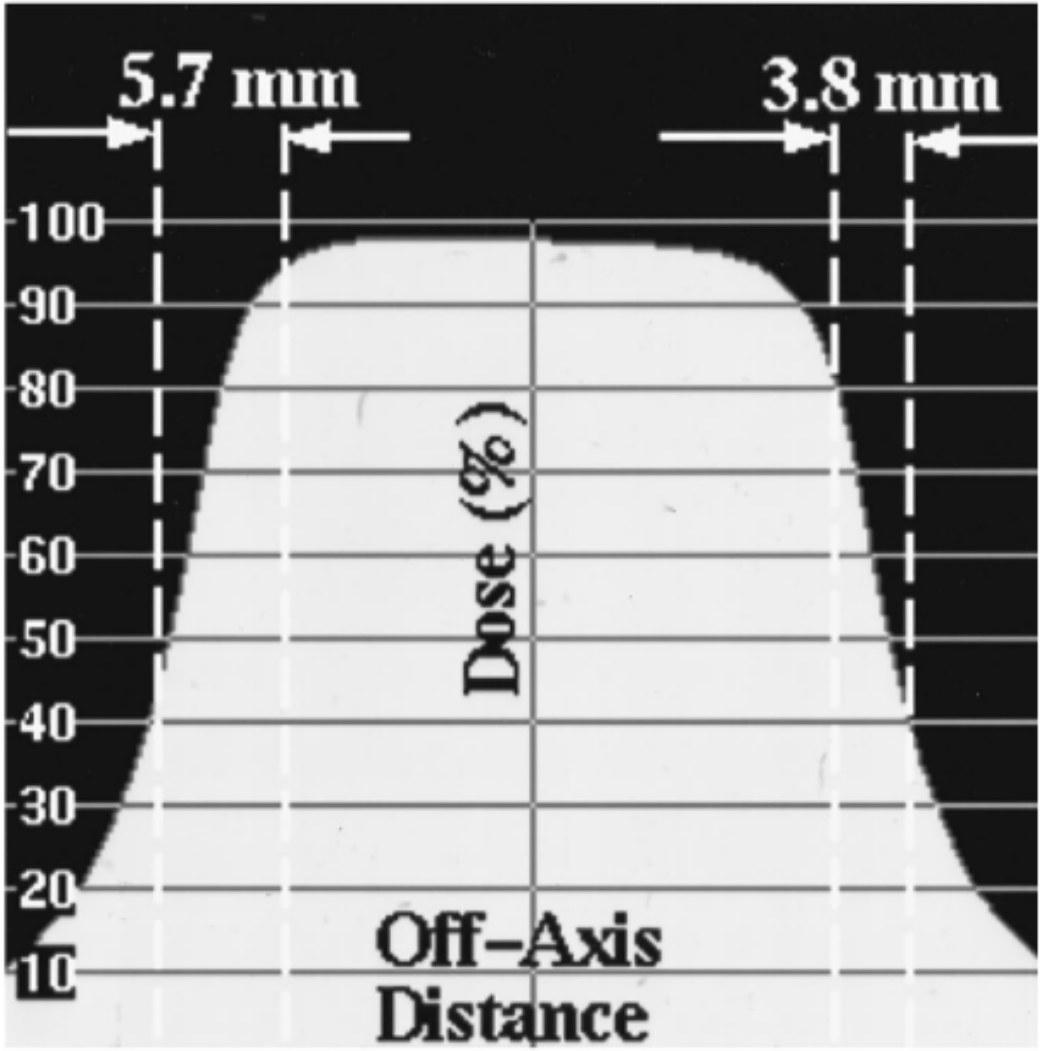



FIG. 3. a Conformity index (Ratio of PD Volume to PTV Volume) vs. homogeneity index.

**Hong *et al.: LINAC-based SRS: Inhomogeneity, conformity, and dose fall off,* Med. Phys., Vol. 38, No. 3, March 2011**

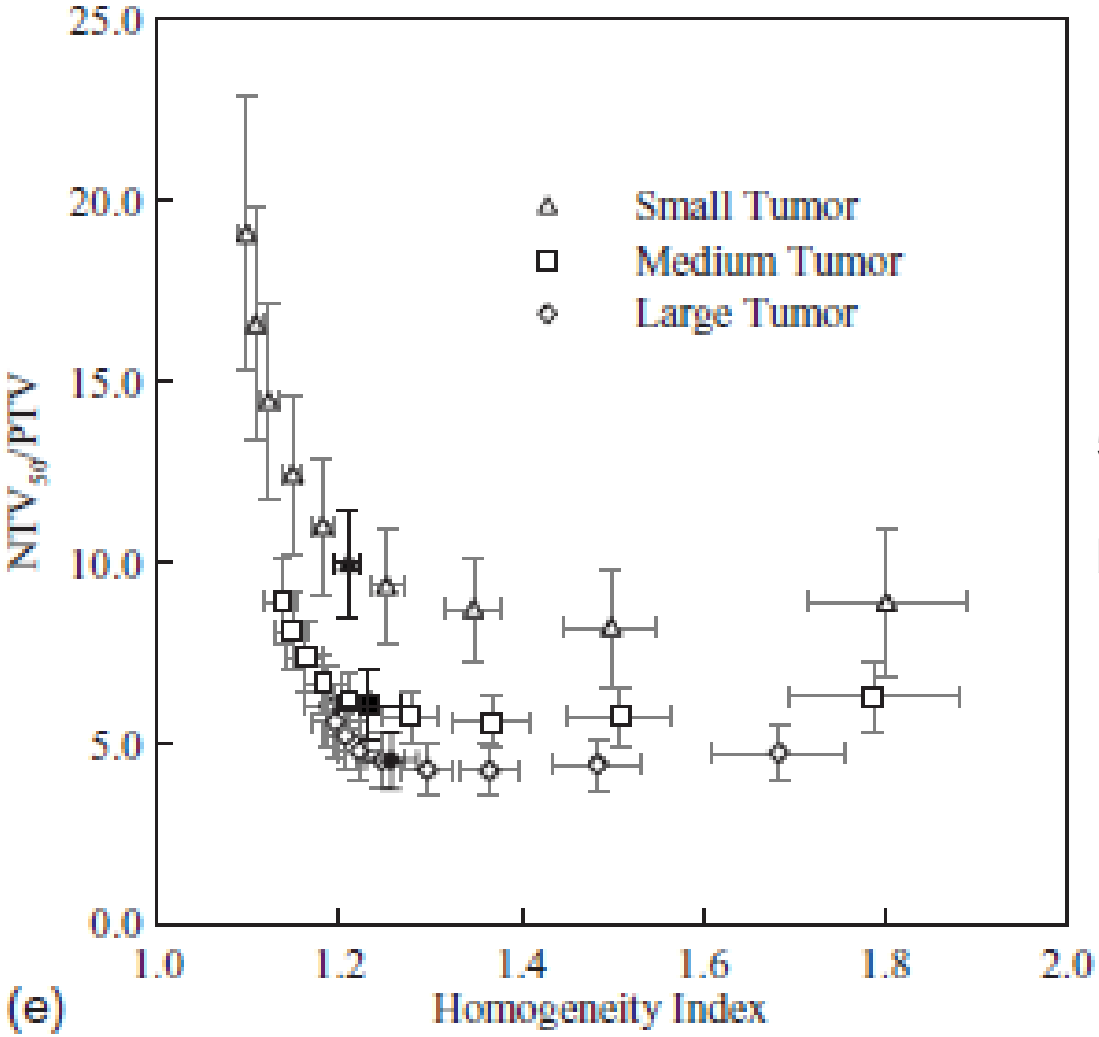



For single isocenter dose distributions, the dose fall-off from prescription isodose to half of the prescription dose typically occurs over the shortest distance if the dose is prescribed to the 80% isodose shell, with 100% as maximum dose.

If 100% is PD, then 125% should be the maximum dose to have sharpest ratio of $R_{50\%}$ (Ratio of 50% Prescription isodose volume to the PTV volume)

Sanford L. Meeks et al Int. J. Radia. Onc. Biol. Phys., Vol. 41, No. 1, pp. 183–197, 1998

# Cranial SRS Planning




Normal Tissue Volume receiving 50% of PD increases sharply as PTV inhomogeneity decreases below 120% of PD

**Hong *et al.: LINAC-based SRS: Inhomogeneity, conformity, and dose fall off,* Med. Phys., Vol. 38, No. 3, March 2011**

| | Conventional | SBRT (Ablative intent) |
|---|---|---|
| PD per fraction | 3Gy or less | 5 Gy or more |
| # of fractions | 10 or more | 5 or less |
| Dose Distribution | Homogeneous (maximum PTV dose ~ 110%) | Heterogeneous (maximum PTV dose up to 160%) |
| Dose Gradient outside PTV | Shallow slope | Steep slope |

# 20Gy x 3 plan is different from 2Gy x 30 plan
## a small lung lesion example (PTV volume 33cc)

| | SBRT | Conventional | |
|---|---|---|---|
| # of Beams | 11 | 11 | 3 |
| Beam Margin (mm) | 1 | 5 | 5 |
| PD per fraction | 20 Gy | 2 Gy | 2 Gy |
| Max PTV Dose (%) | 124.2% | 110.8% | 110.0% |
| $V_{100\%}$ | 38.6 cc | 44.3 cc (5.7 cc more) | 87.5 cc (48.9 cc more) |
| $V_{50\%}$ ($R_{50\%}$) | 146.3 cc (4.4) | 212.4 cc (6.4) (66cc more) | 417.3 cc (12.6) (271 cc more) |
| $V_{25\%}$ | 630.4 cc | 799.2 cc (169 cc more) | 756.8 cc (126 cc more) |
| 50% PD | 10 Gy | 1 Gy | 1 Gy |

All Plans normalized to PTV V100% = 95%

## For SBRT plans

Prescription Isodose level is usually not 100% PD covering 100% PTV

Often 95% PD covering 95% PTV or higher
Or 100% PD covering 95% PTV or higher

This coverage was chosen because of the increased tissue volumes that must be irradiated to cover the corners of the PTV on each consecutive CT slice if 100% coverage is required.

## For conventional plans

Often 100% PD dose to 100% PTV

# SBRT planning principles are very similar to Cranial SRS planning principles

- Inhomogeneous Dose inside PTV
- Sharp Dose Fall Off outside PTV
- Multiple non-coplanar beams or arcs are needed to create conformal dose distributions.

  Much more limited non-coplanar beam clearance compared with cranial SRS for LINAC based SBRT.

# Requirements of SBRT Plan
## (from RTOG 0813 and 0915 lung protocols)

- **Maximum Dose:** normalized to 100%, must be within PTV
- **Prescription Isodose:** must be ≥ 60% and < 90% of the maximum dose
- **Prescription Isodose Surface Coverage:** 95% of the target volume (PTV) is conformally covered by the prescription isodose surface (PTV V100%PD = 95%) and 99% of the target volume (PTV) receives a minimum of 90% of the prescription dose (PTV V90%PD > 99%)
- **High Dose Spillage**: The cumulative volume of all tissue outside the PTV receiving a dose > 105% of prescription dose should be no more than 15% of the PTV volume
- **Intermediate Dose Spillage:** The falloff gradient beyond the PTV extending into normal tissue structures must be rapid in all directions and meet the criteria in Table1
- **Meet the constraints of dose limiting organs at risk**

**Table 1: Conformality of Prescribed Dose for Calculations Based on Deposition of Photon Beam Energy in Heterogeneous Tissue**

| PTV Volume (cc) | Ratio of Prescription Isodose Volume to the PTV Volume | | Ratio of 50% Prescription Isodose Volume to the PTV Volume, $R_{50\%}$ | | Maximum Dose (in % of dose prescribed) @ 2 cm from PTV in Any Direction, $D_{2cm}$ (Gy) | | Percent of Lung Receiving 20 Gy Total or More, $V_{20}$ (%) | |
|---|---|---|---|---|---|---|---|---|
| | Deviation | | Deviation | | Deviation | | Deviation | |
| | None | Minor | None | Minor | None | Minor | None | Minor |
| 1.8 | <1.2 | <1.5 | <5.9 | <7.5 | <50.0 | <57.0 | <10 | <15 |
| 3.8 | <1.2 | .<1.5 | <5.5 | <6.5 | <50.0 | <57.0 | <10 | <15 |
| 7.4 | <1.2 | <1.5 | <5.1 | <6.0 | <50.0 | <58.0 | <10 | <15 |
| 13.2 | <1.2 | <1.5 | <4.7 | <5.8 | <50.0 | <58.0 | <10 | <15 |
| 22.0 | <1.2 | <1.5 | <4.5 | <5.5 | <54.0 | <63.0 | <10 | <15 |
| 34.0 | <1.2 | <1.5 | <4.3 | <5.3 | <58.0 | <68.0 | <10 | <15 |
| 50.0 | <1.2 | <1.5 | <4.0 | <5.0 | <62.0 | <77.0 | <10 | <15 |
| 70.0 | <1.2 | <1.5 | <3.5 | <4.8 | <66.0 | <86.0 | <10 | <15 |
| 95.0 | <1.2 | <1.5 | <3.3 | <4.4 | <70.0 | <89.0 | <10 | <15 |
| 126.0 | <1.2 | <1.5 | <3.1 | <4.0 | <73.0 | >91.0 | <10 | <15 |
| 163.0 | <1.2 | <1.5 | <2.9 | <3.7 | <77.0 | >94.0 | <10 | <15 |

Note 1: For values of PTV dimension or volume not specified, linear interpolation between table entries is required.

Note 2: Protocol deviations greater than listed here as “minor” will be classified as “major” for protocol compliance (see Section 6.7).

RTOG 0813 (lung) and RTOG 0915 (lung) Table1

The published protocols usually do not specify $R_{50\%}$ or $D_{2cm}$ requirements for spine and liver cases. Nevertheless, we find lung protocol criteria useful for spine and liver cases as well.

# RTOG 0631 (Spine)
# Definition of Spine Metastasis Target Volume

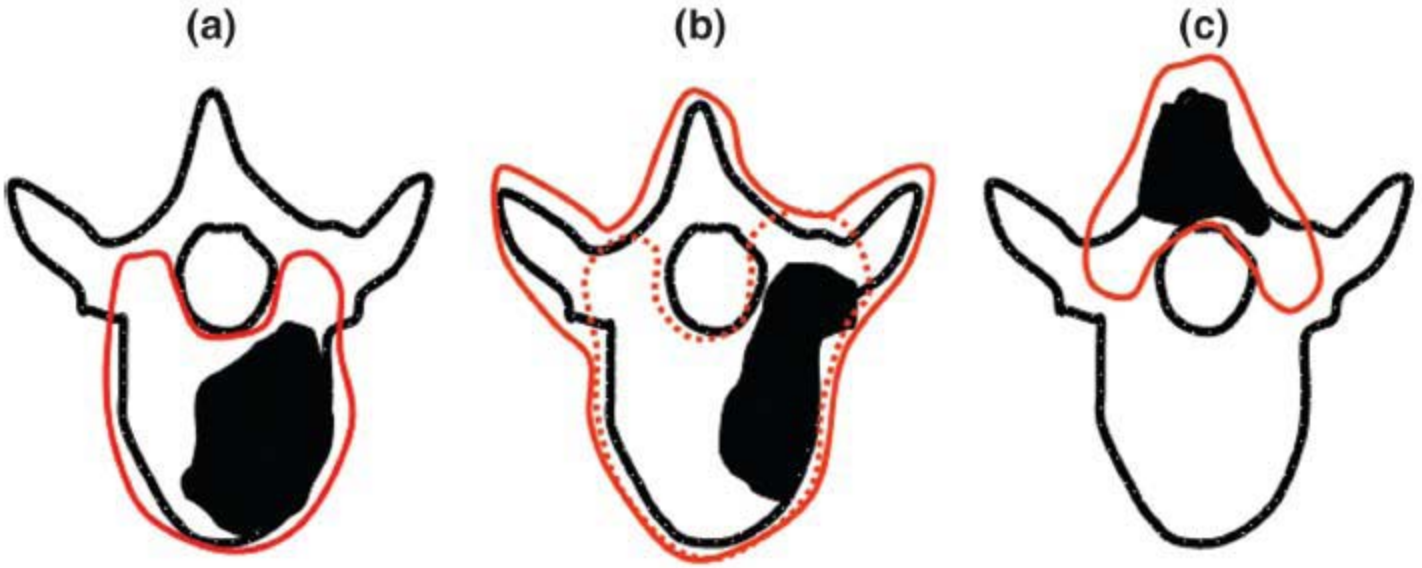
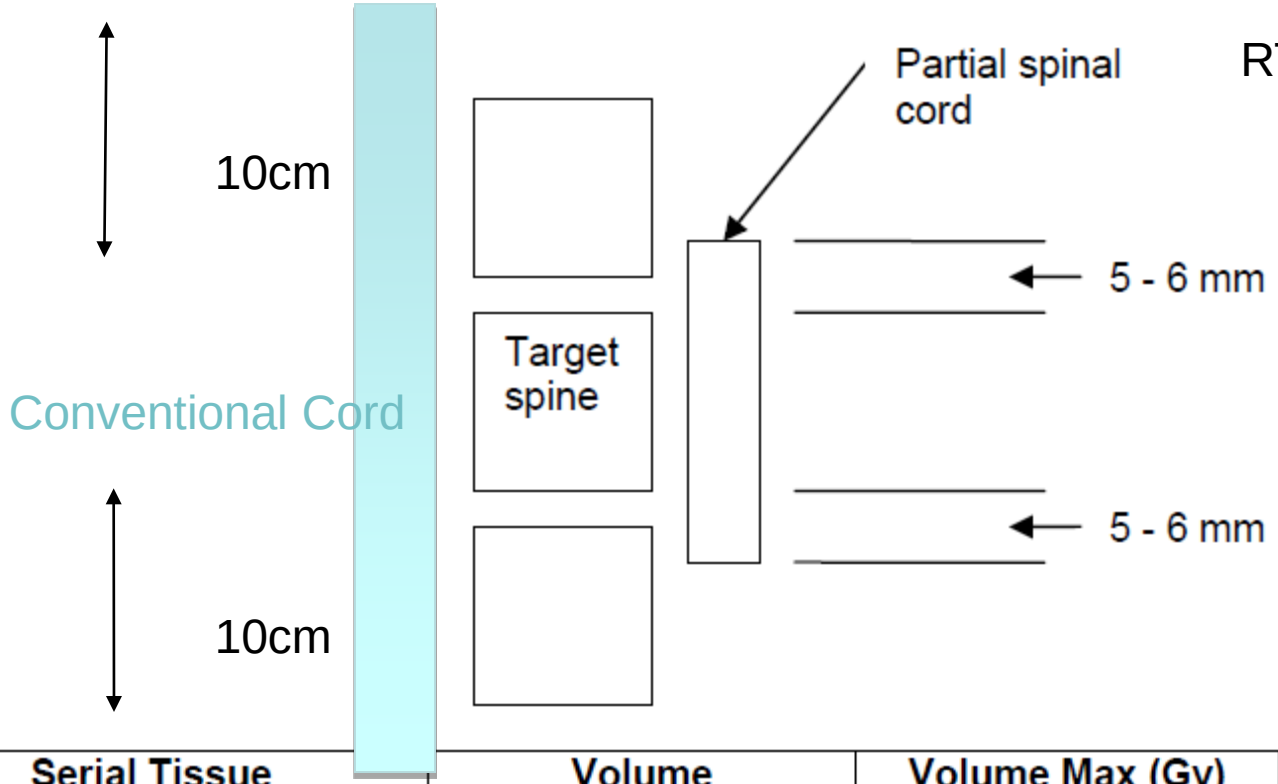



**Figure 2: Diagram of Spine Metastasis and Target Volume**

**An epidural lesion is included in the target volume provided that there is a ≥ 3 mm gap between the spinal cord and the edge of the epidural lesion.**

## Figure 3: Diagram of Defining Partial Spinal Cord Volume

RTOG 0631 (Spine)




| Serial Tissue | Volume | Volume Max (Gy) | Endpoint (≥ Grade 3) |
|---|---|---|---|
| | | | |
| Spinal Cord | Less than or equal to 0.35cc | 10 Gy | myelitis |
| **AND** | | | |
| Spinal Cord | Less than or equal to 10% of the partial spinal cord | 10 Gy | myelitis |
| **AND** | | | |
| Spinal Cord | Less than or equal to 0.03cc | 14 Gy | myelitis |
| *Cauda Equina* | <0.03 cc<br><5 cc | 16 Gy<br>14 Gy | neuritis |

~~Max point dose~~

# Montefiore-Einstein Cancer Center
# SBRT Registry Study

Spine

*1-3 lesions*

- Single Fraction: 16 Gy (RTOG 0631)

  (for cases we have confidence in setup, for example: inferior T-spine and L-spine lesions)
- Three Fraction: 24 Gy (8 Gy per fraction)

  (for cases with setup uncertainty large, for example: C-spine and superior T-spine lesions)

## For Spine Cases:

IMRT or VMAT is required to create concave dose distributions.

We use two full RapidArcs, or two partial RapidArcs to avoid shoulders or arms, one arc with collimator at 0, the other with collimator at 90.

Multiple fixed IMRT fields can be used.

No need to do any non-coplanar beams (no clearance anyway).

We follow RTOG 0813 and RTOG 0915 lung protocols criteria for PTV coverage, high dose spillage and dose fall off

**Maximum Dose:** must be within PTV

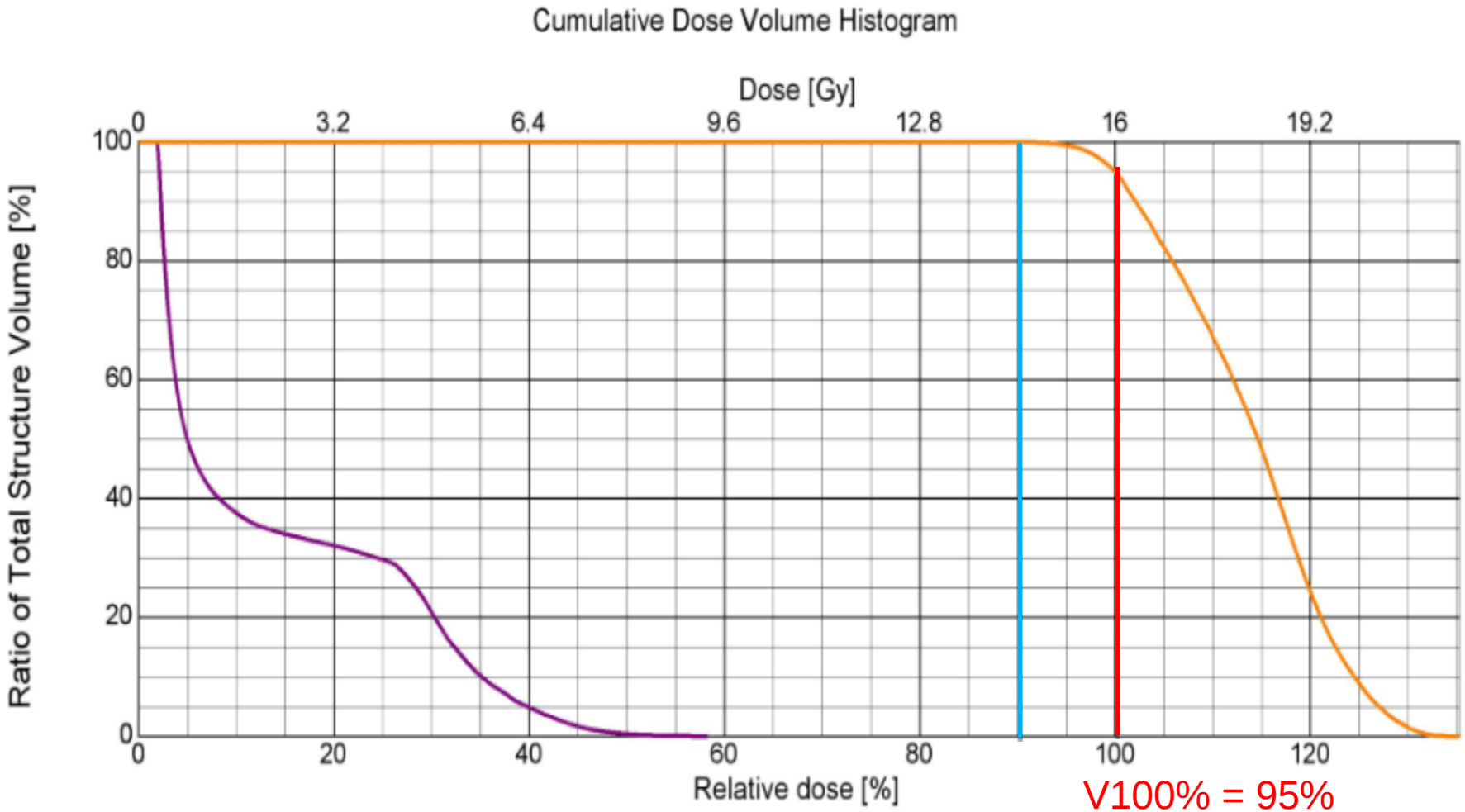
**Prescription Isodose:** If PD = 100%, maximum dose must be at least 111.11% but not more than 166.67%

**Prescription Isodose Surface Coverage:**

95% of the target volume (PTV) is conformally covered by the prescription isodose surface (PTV V100% = 95%)

and

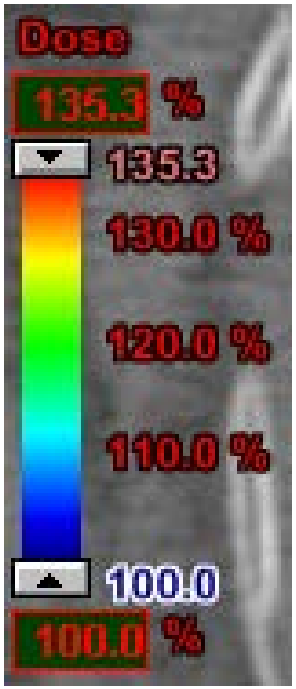
99% of the target volume (PTV) receives a minimum of 90% of the prescription dose (PTV V90% > 99%)




| Structure | Structure Status | Coverage [%/%] | Volume | Min Dose | Max Dose | Mean Dose | Modal Dose | Median Dose | Std Dev |
|---|---|---|---|---|---|---|---|---|---|
| RTOG-F-CORD | Unapproved | 100.0 / 100.0 | 8.4 cm³ | 1.8 % | 58.3 % | 13.7 % | 2.1 % | 5.0 % | 14.0 % |
| RTOG-PTV | Unapproved | 100.0 / 100.0 | 19.1 cm³ | 88.3 % | 135.3 % | 113.8 % | 116.3 % | 114.6 % | 8.3 % |

Cord: Max point dose 9.33 Gy

## Prescription Isodose Surface Coverage:




PD = 100% = 16 Gy

PTV V100 = 95%

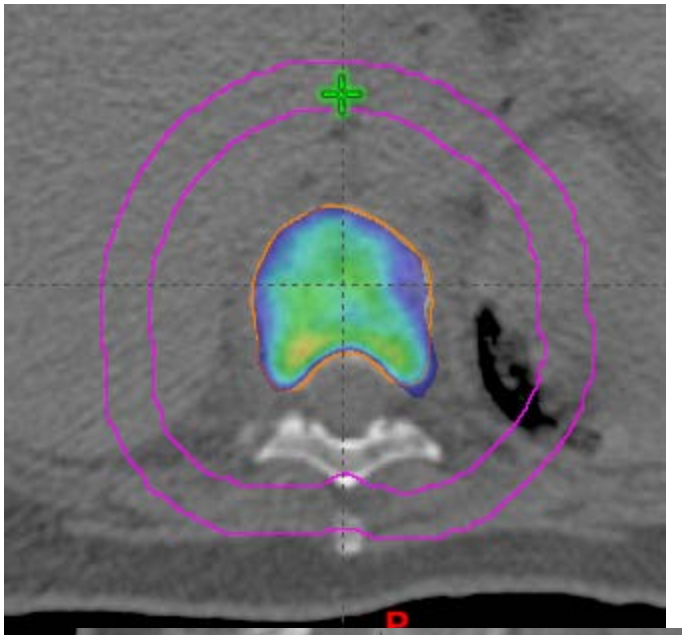
PTV V100 = 95%

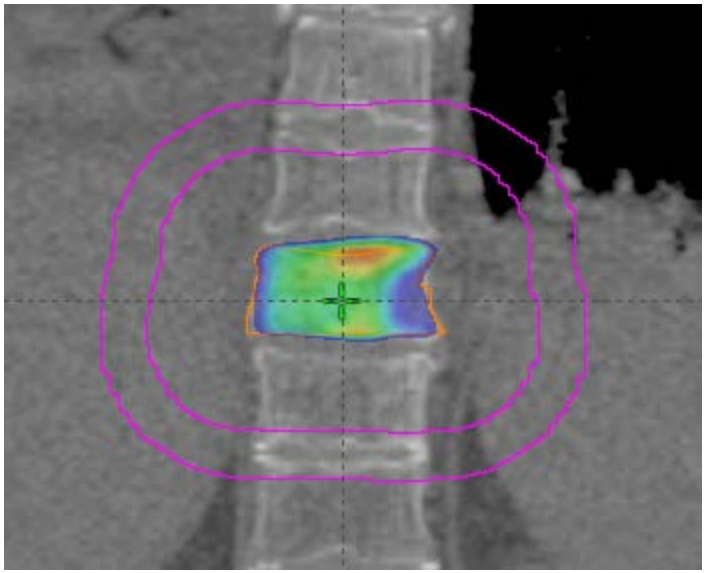
100% PD and Above

PTV

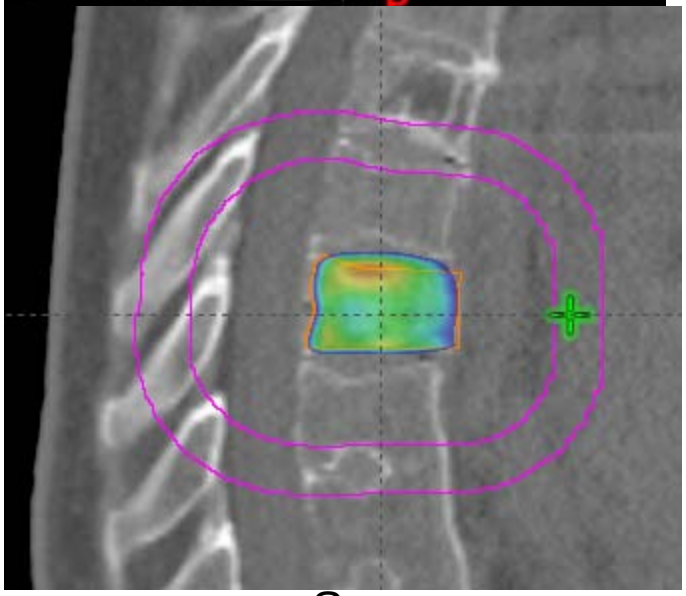
2cm-3cm ring

CAX



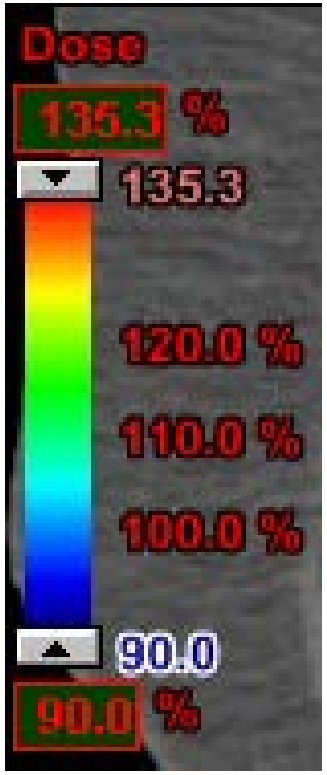


Cor



Sag

## Prescription Isodose Surface Coverage:

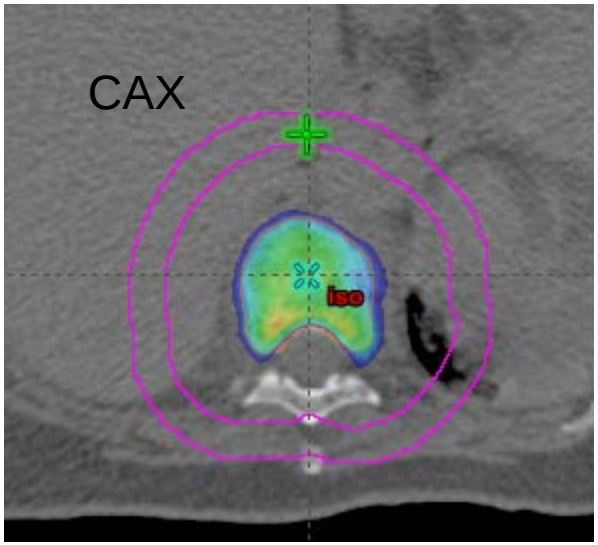


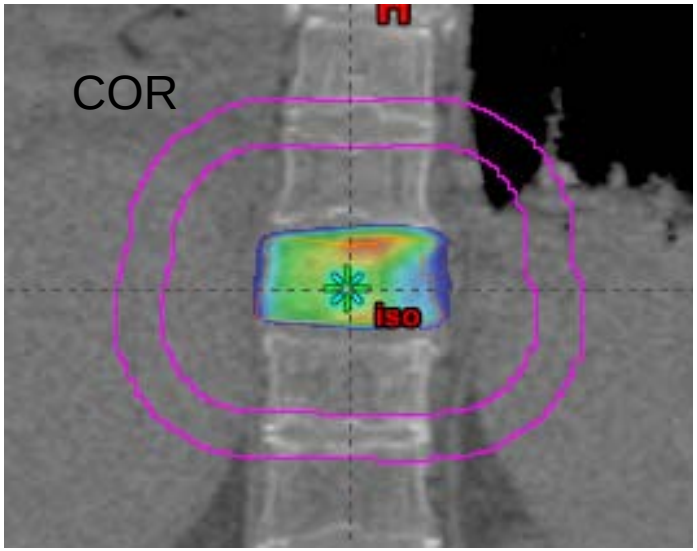

PD = 100% = 16 Gy

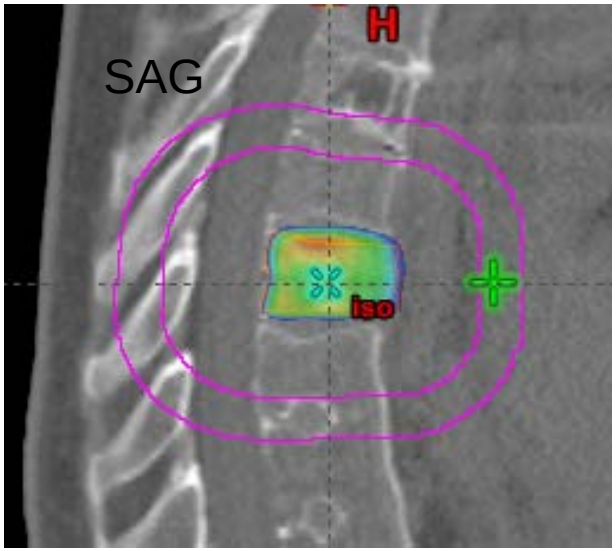
PTV V90% > 99%

Here PTV V90% = 100%

90% PD and Above



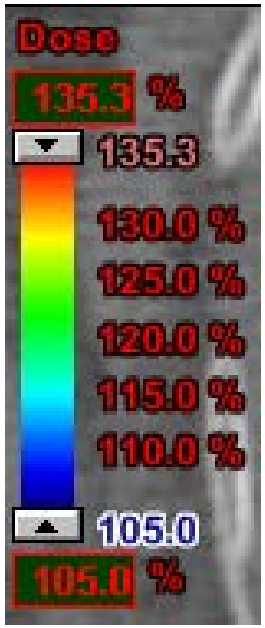




PTV

2cm-3cm ring

# High Dose Spillage:

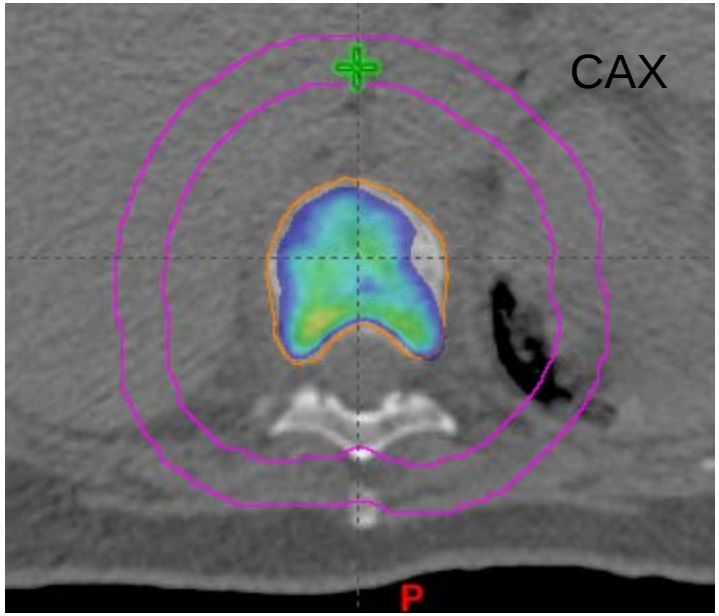


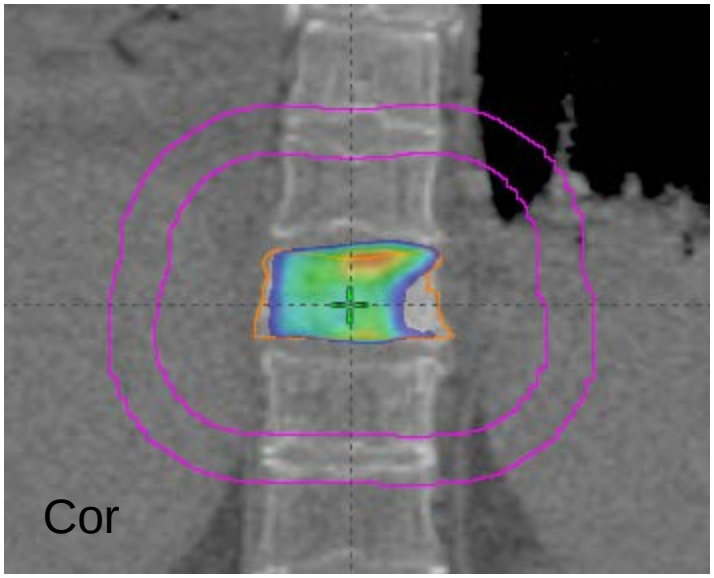

PD = 100% = 16 Gy
Max PTV dose = 135.3%

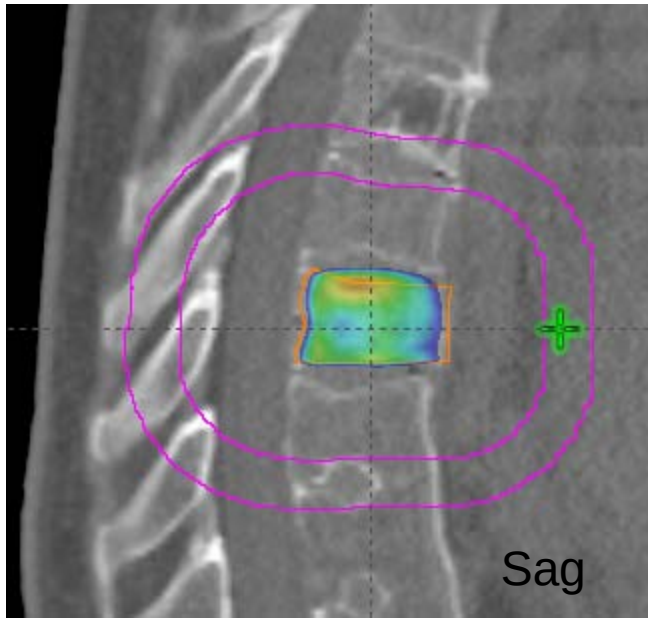
105% covered volumes outside of PTV <= 15% of volume of PTV

Here PTV = 19.1cc
V105-PTV = 1.4 cc (7.3%)

105% PD and Above



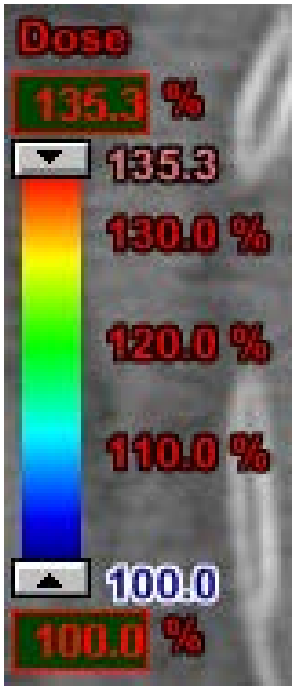




PTV

2cm-3cm ring

# Conformality : Prescription Dose Volume vs. PTV Volume

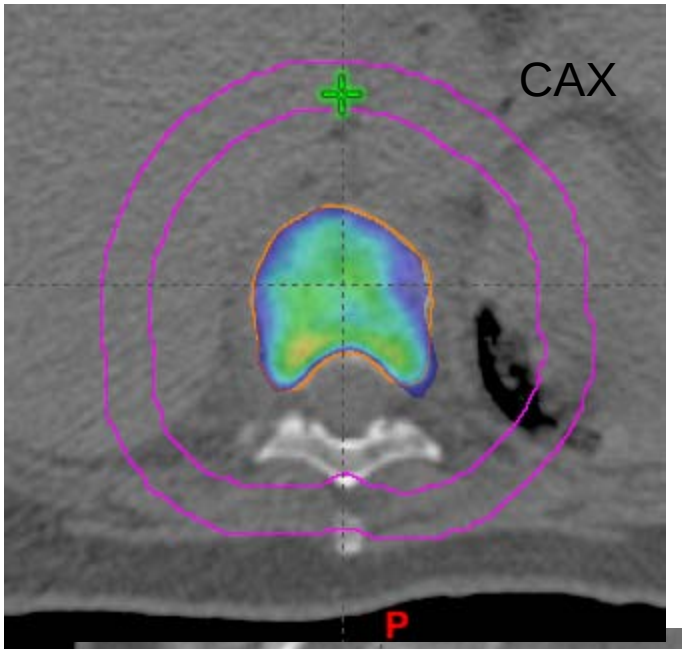


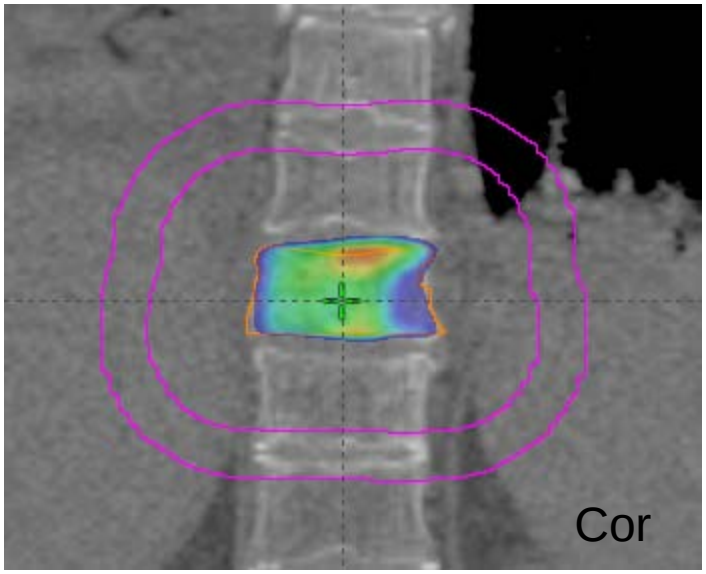

PD = 100% = 16 Gy

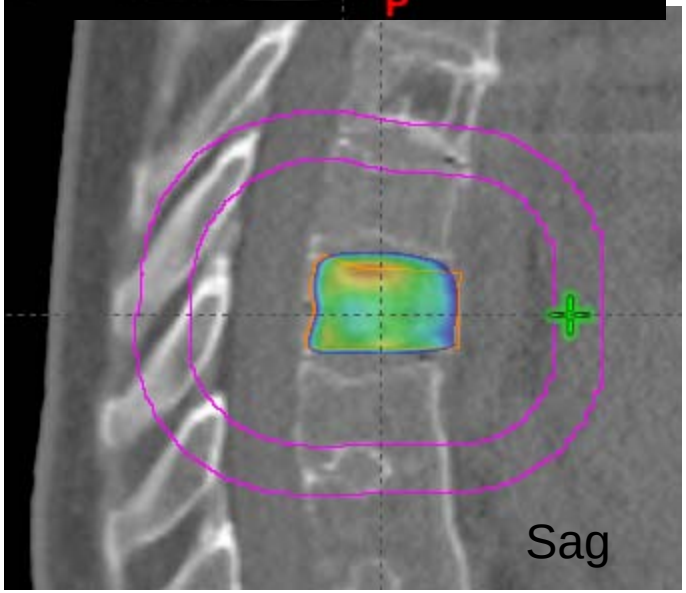
V100 / PTV volume <= 1.2

Here PTV = 19.1cc
V100 = 21.7 cc
Ratio = 1.14

100% PD and Above



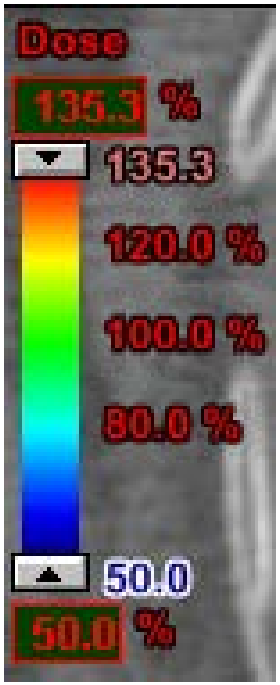




PTV

2cm-3cm ring

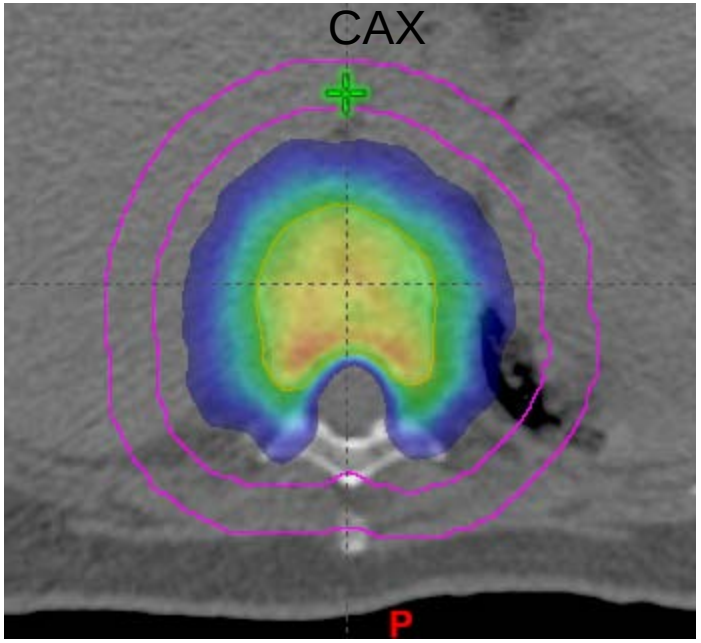
# Intermediate Dose Spillage: $R_{50\%}$ and $D_{2cm}$

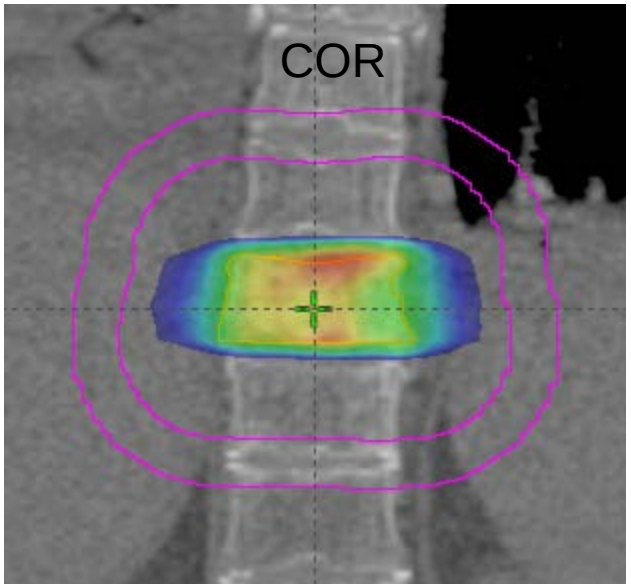


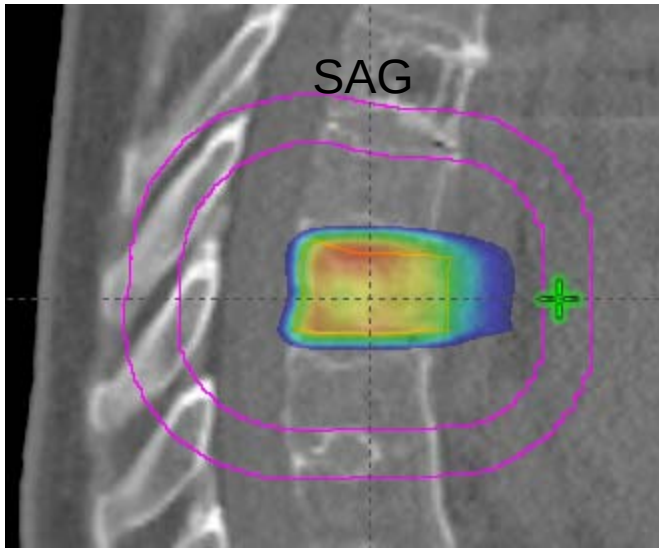

For PTV = 19.1 cc
$R_{50\%}$ < 4.6; $D_{2cm}$ = 52.7%

Here V50% = 77.0 cc
$R_{50\%}$ = 4.0
$D_{2cm}$ = 43.6%

50% PD and Above



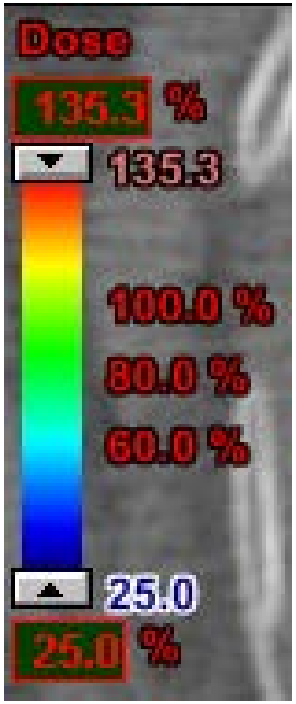



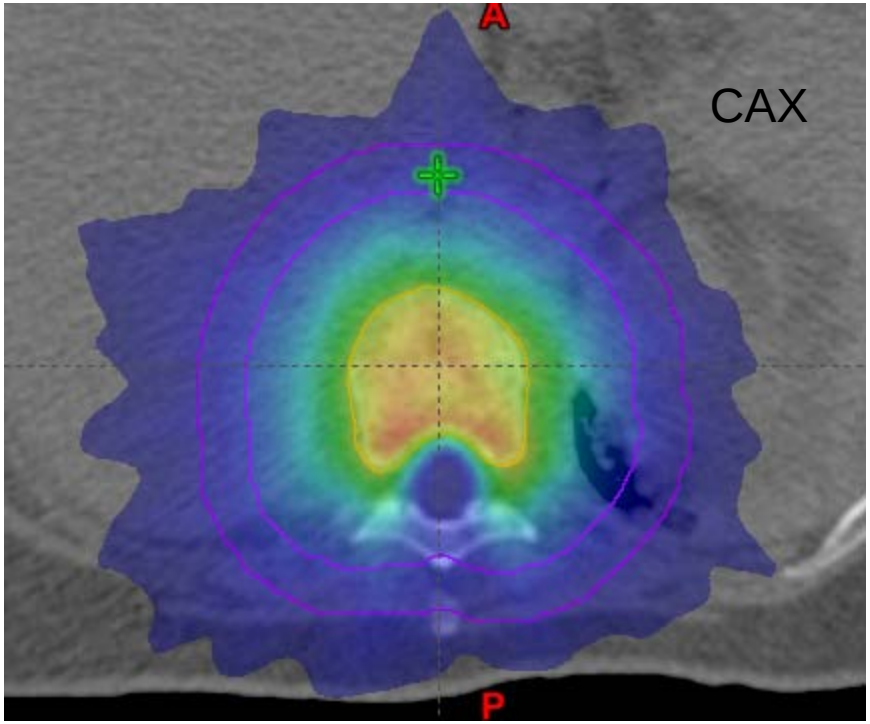

PTV

2cm-3cm ring

**$R_{50\%}$ :** Ratio of 50% PD volume/PTV volume

**$D_{2cm}$ :** Maximum dose in % of PD at 2cm beyond PTV in any direction



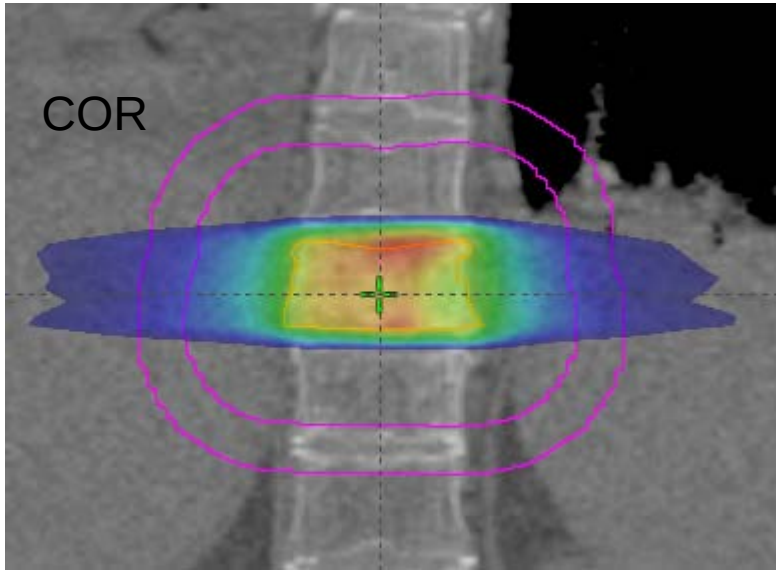



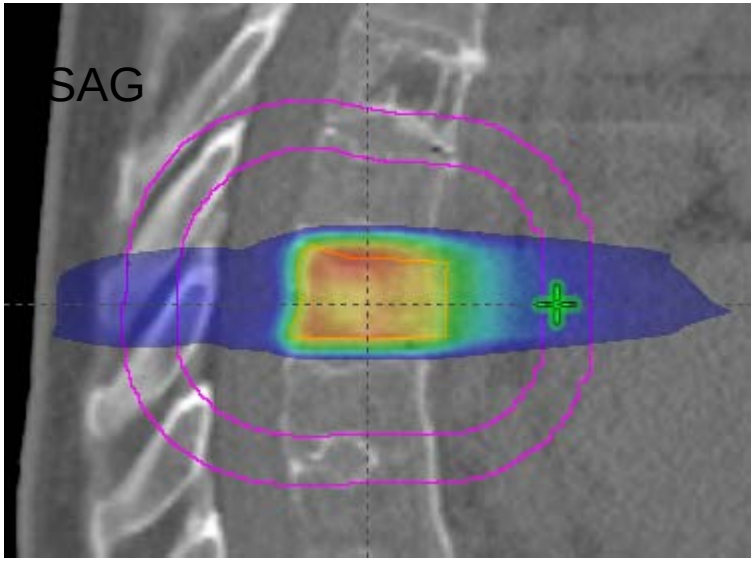

No need to do any non-coplanar beams (no clearance anyway).

25% PD and Above

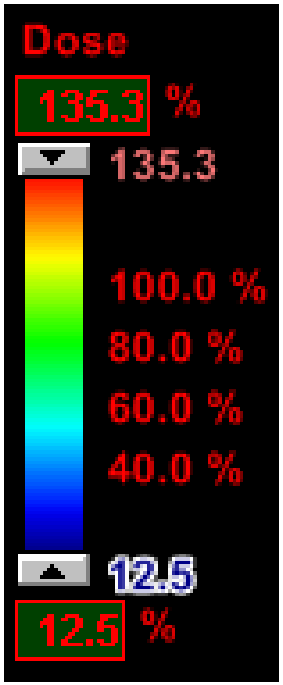
PTV

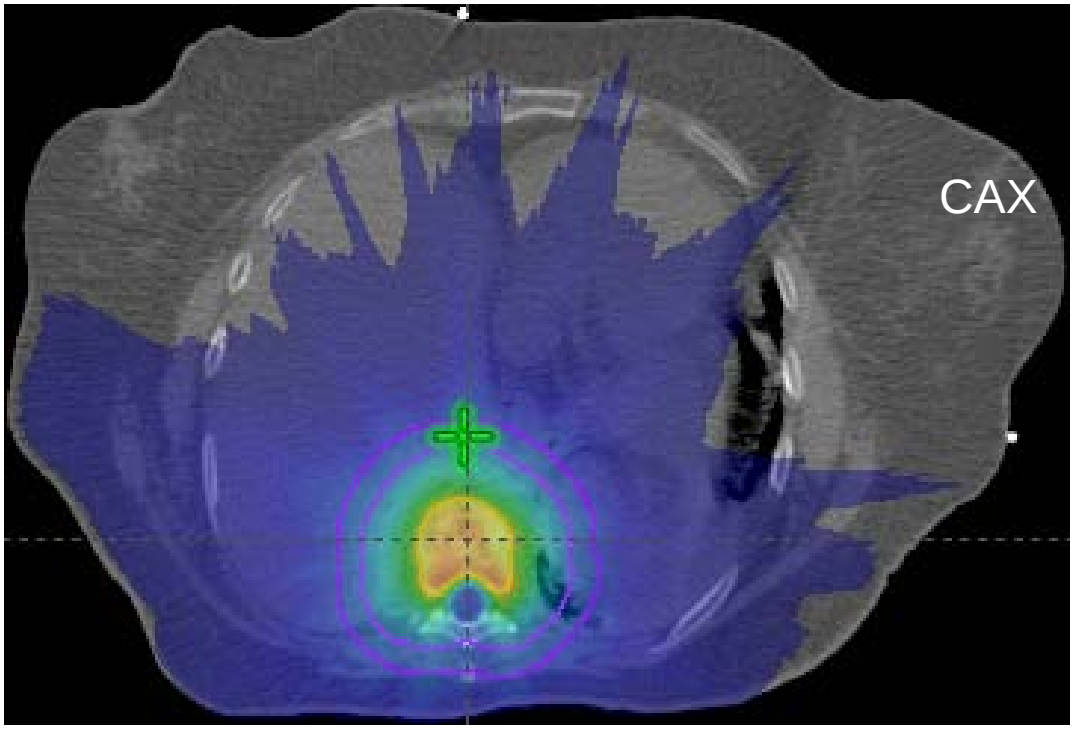
2cm-3cm ring



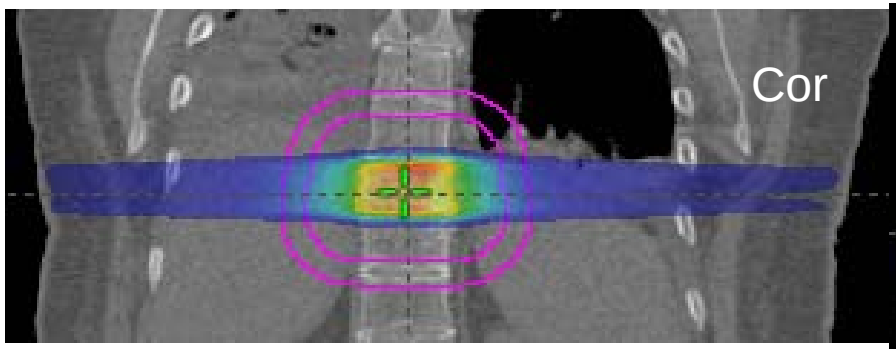



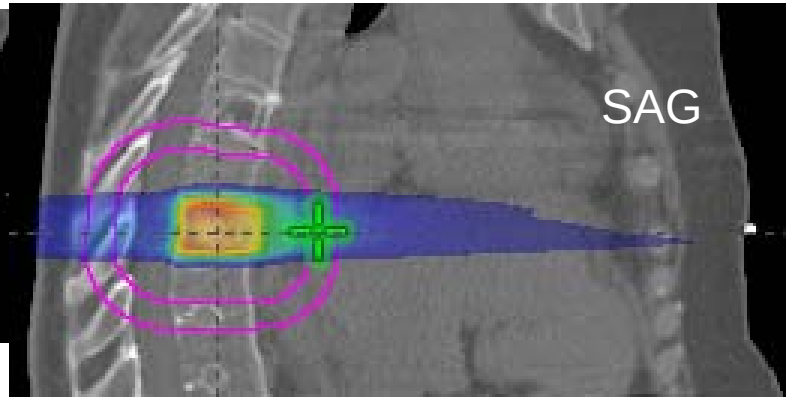
12.5% PD and Above




16Gy x 12.5% = 2Gy

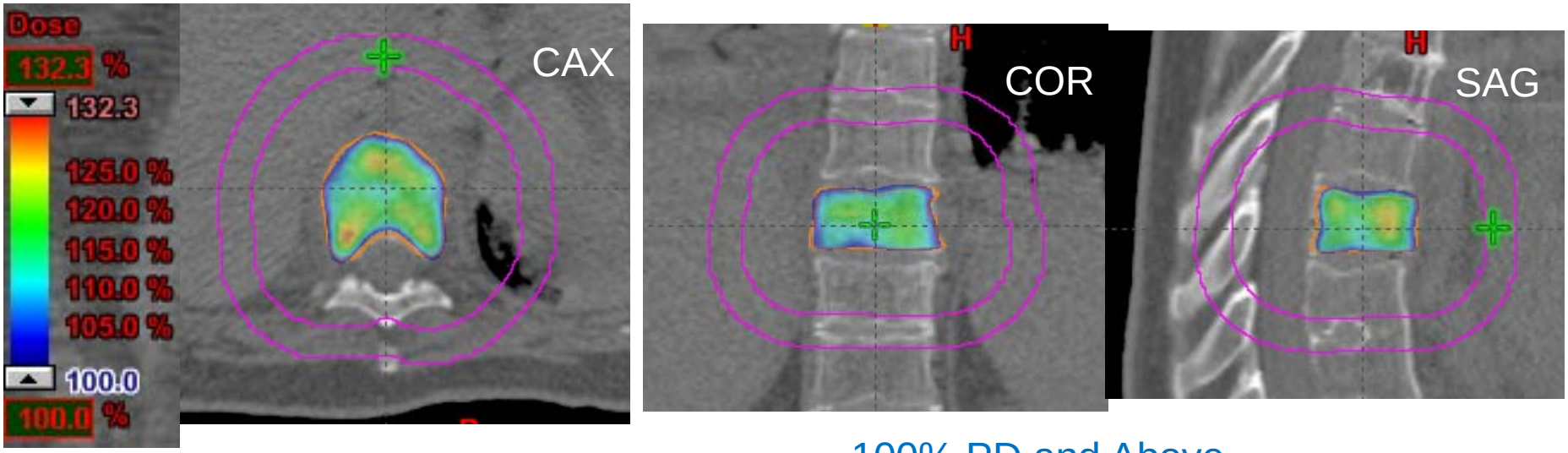



PTV

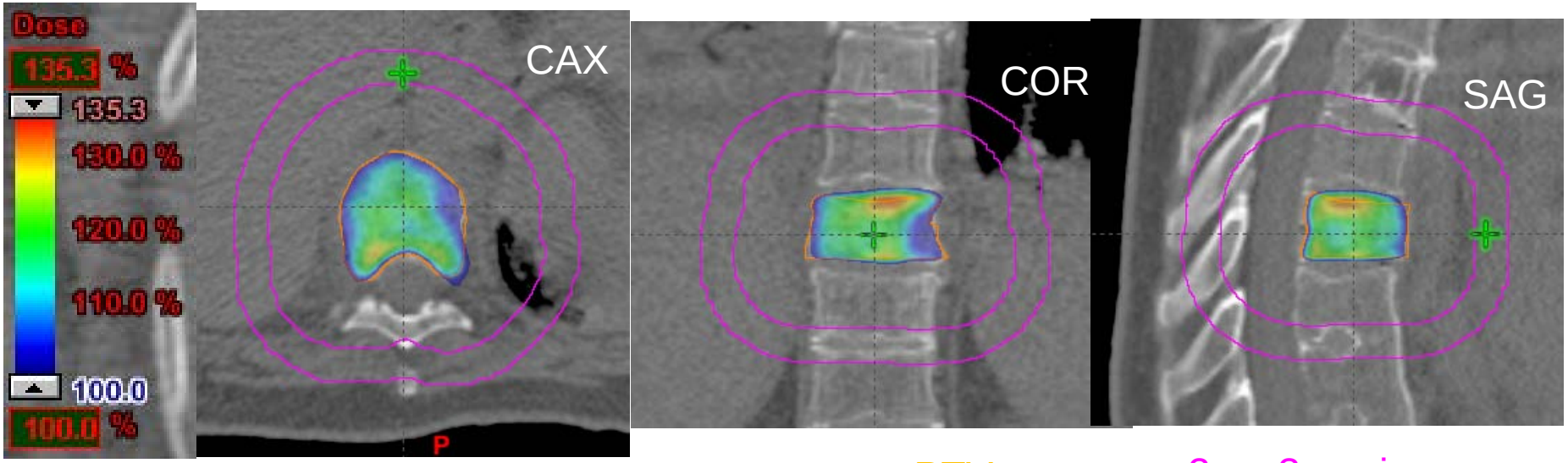
2cm-3cm ring

Single Arc Collimator 45



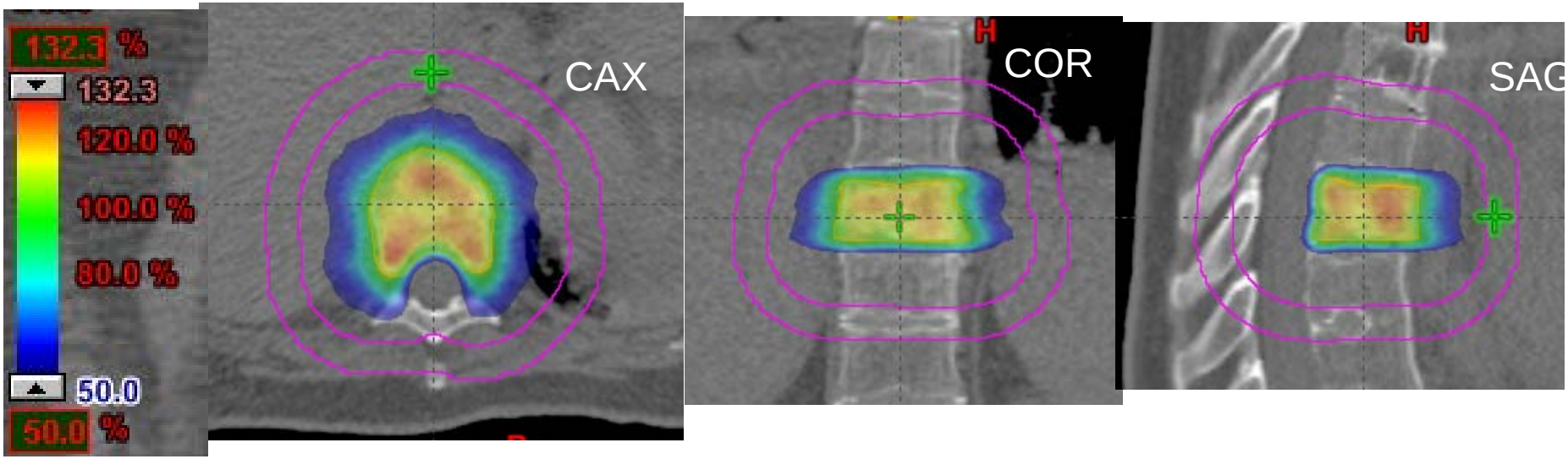

100% PD and Above

Two Arcs: Collimator 0 and 90



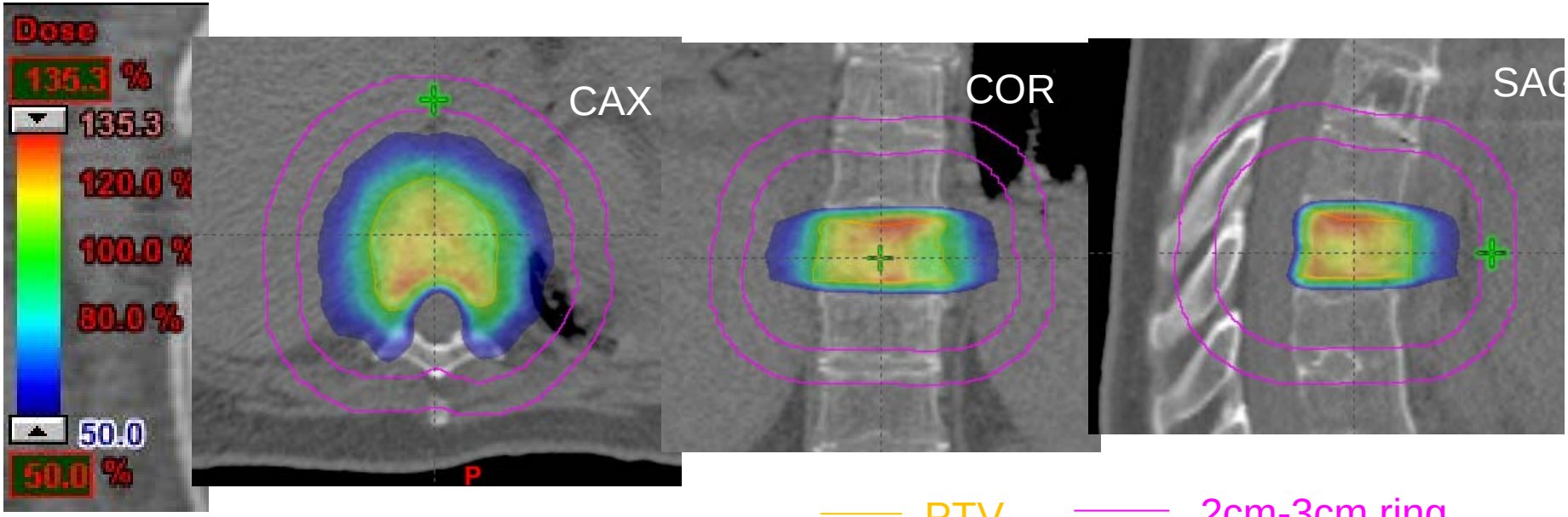

PTV 2cm-3cm ring

Single Arc Collimator 45




Two Arcs: Collimator 0 and 90

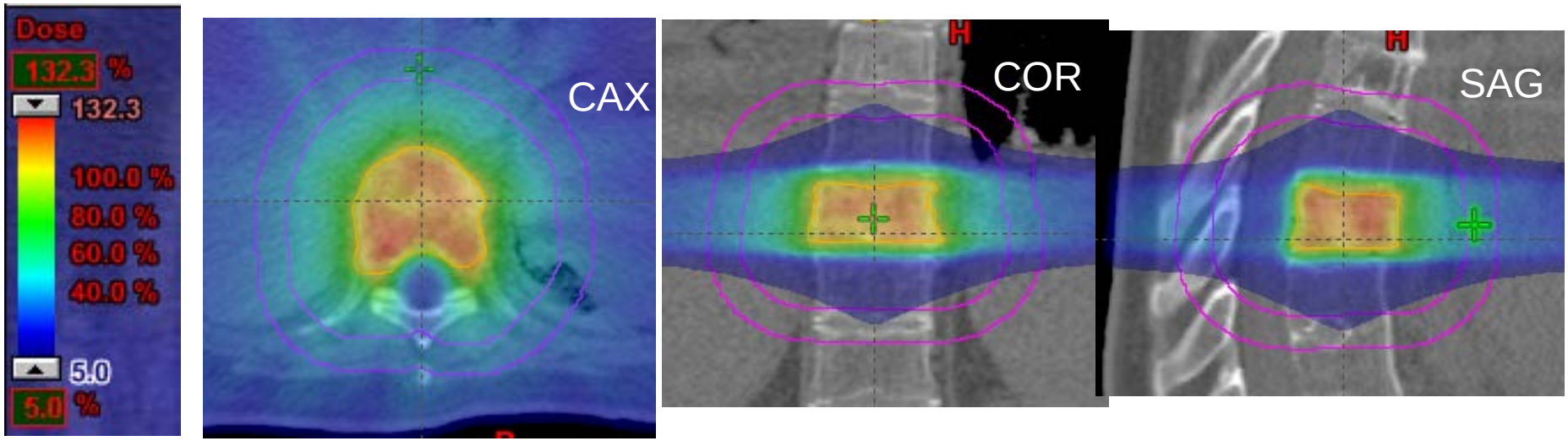
50% PD and Above




PTV

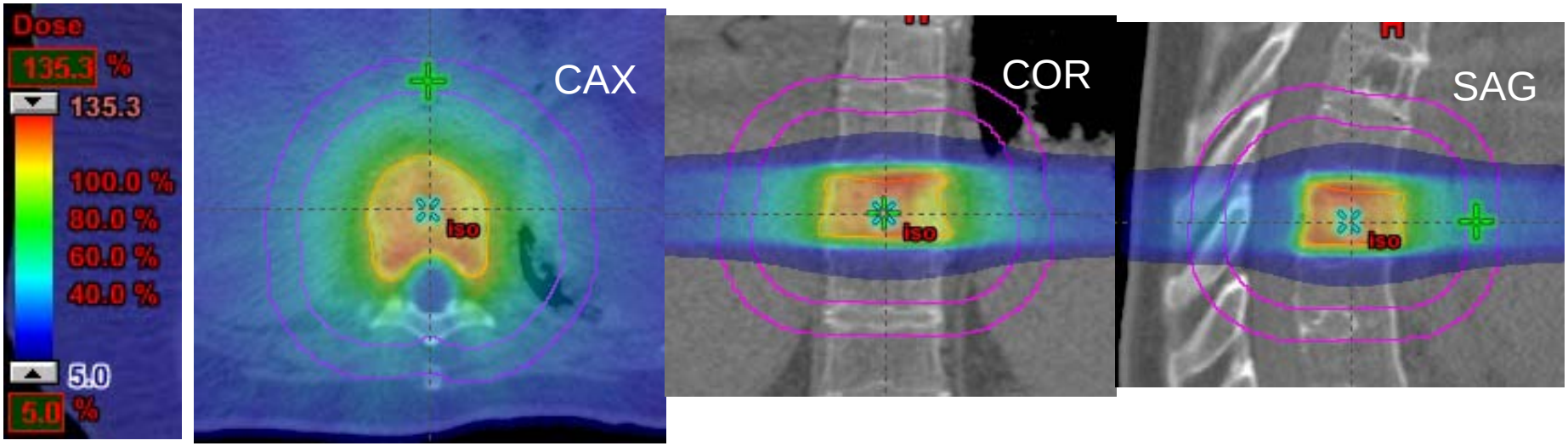
2cm-3cm ring

Additional 15 cc volume of normal tissue receiving 5% PD




Single Arc Collimator 45

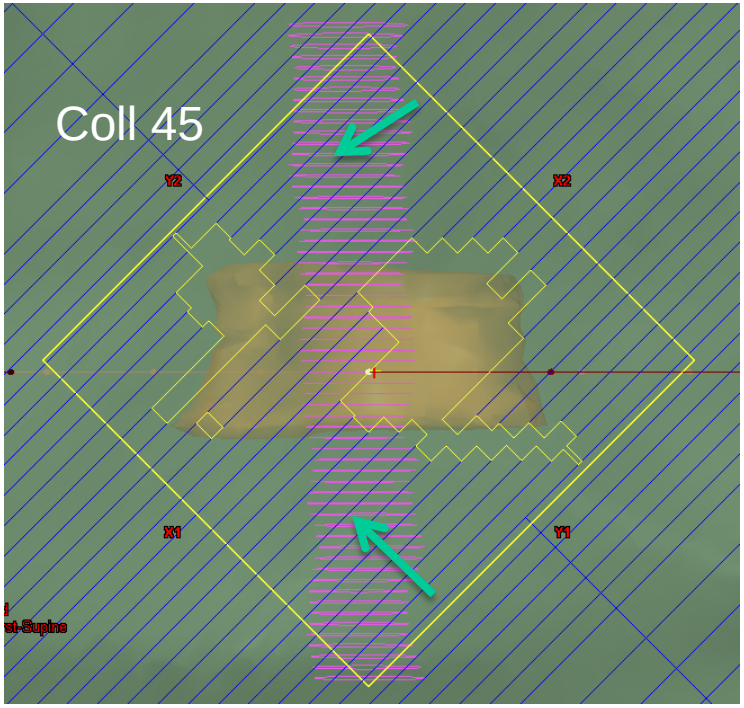
5% PD and Above




Two Arcs: Collimator 0 and 90

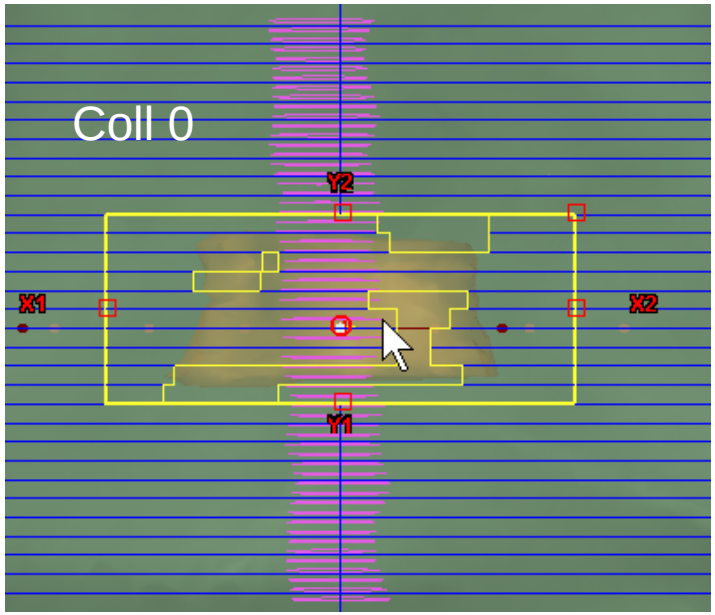
PTV

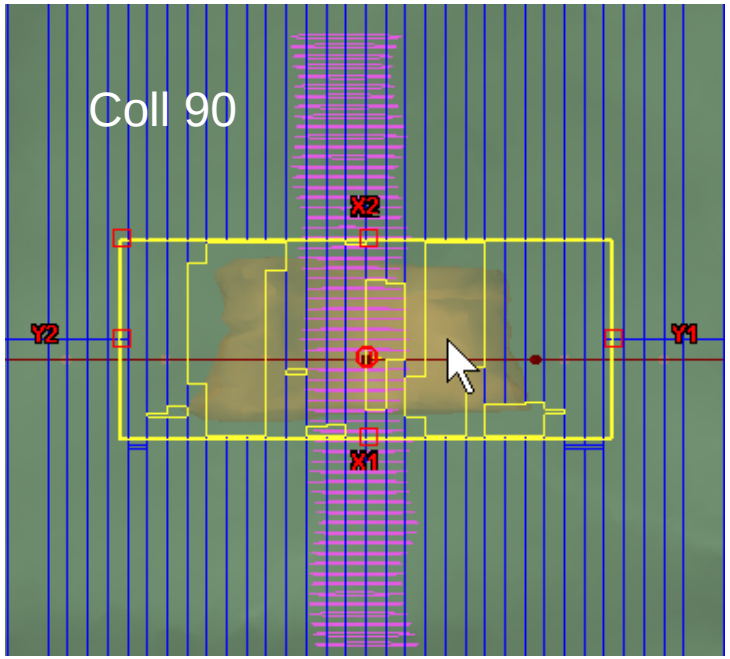
2cm-3cm ring




Jaw opening area twice as much
When compared to collimator
At 0 or 90.
← More leakage dose in
Superior and inferior beyond PTV.

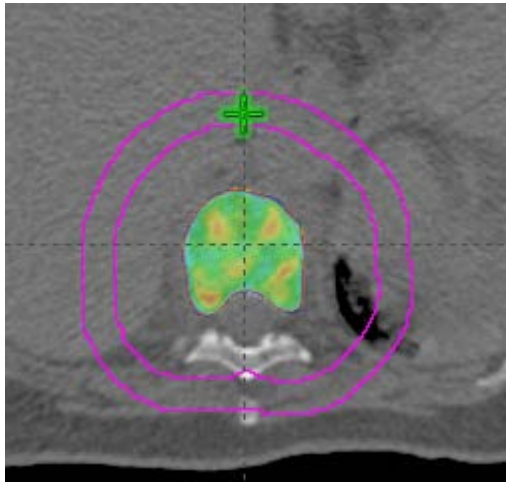
Leaves parked inside jaws when
Unused for RapidArc



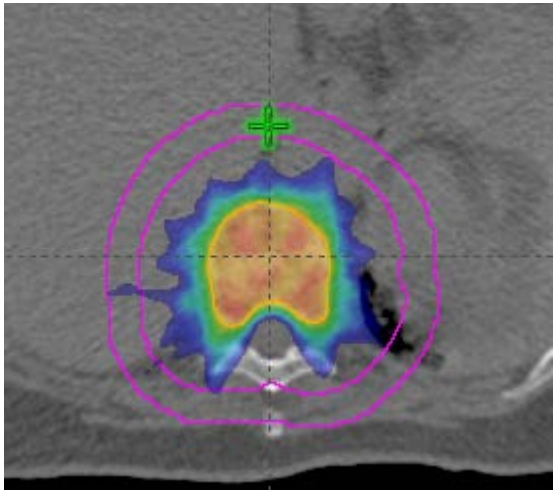



# Fixed IMRT Fields

100% PD and above



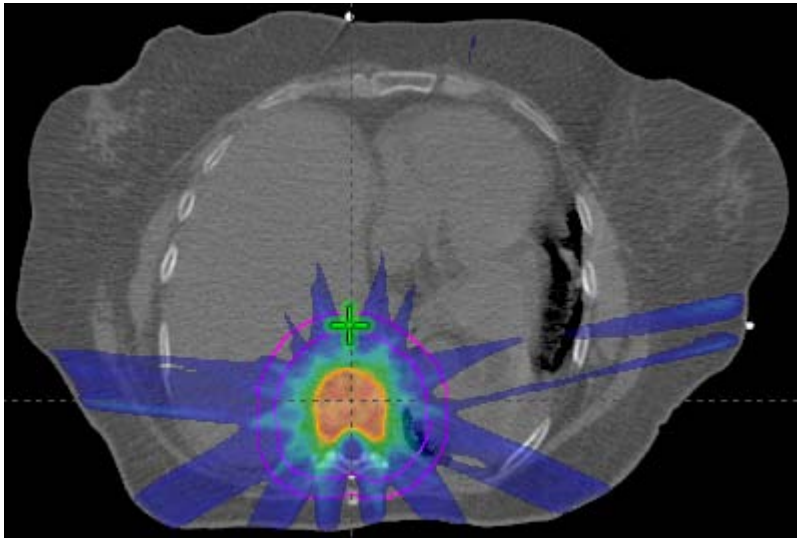
50% PD and above



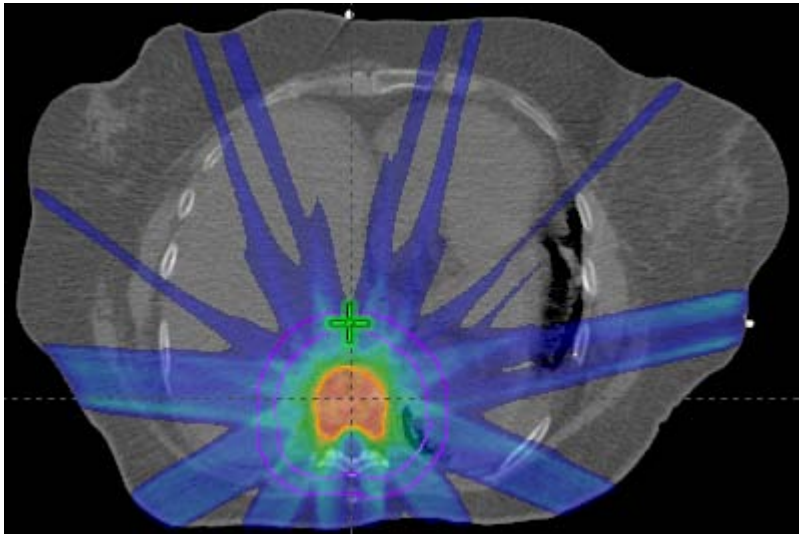
11 fixed field IMRT

Can meet similar $R_{50\%}$ and $D_{2cm}$ constraints

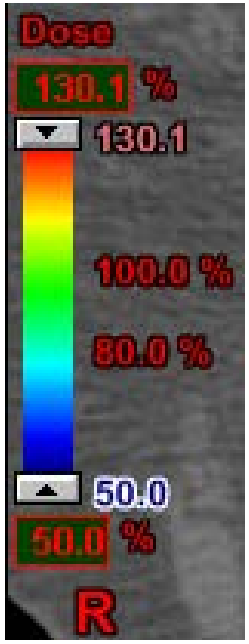
25% PD and above



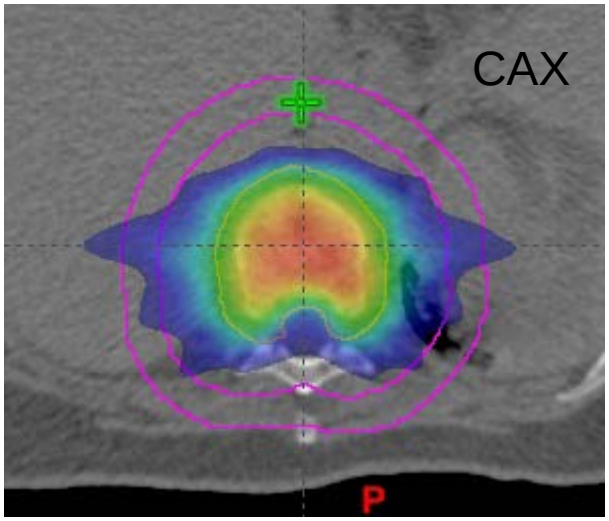
12.5% PD and above



# Fixed IMRT Fields: 7-9 posterior beams



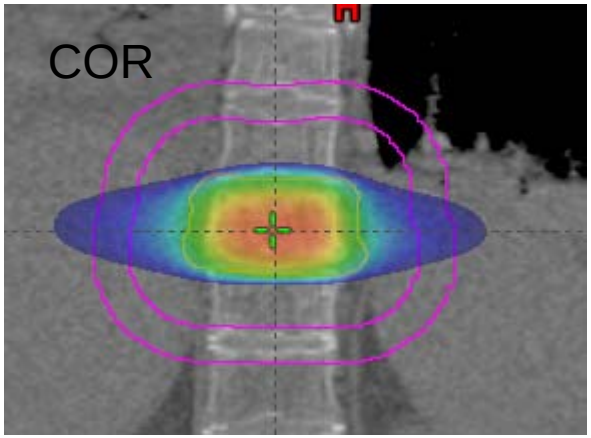

9 Field IMRT

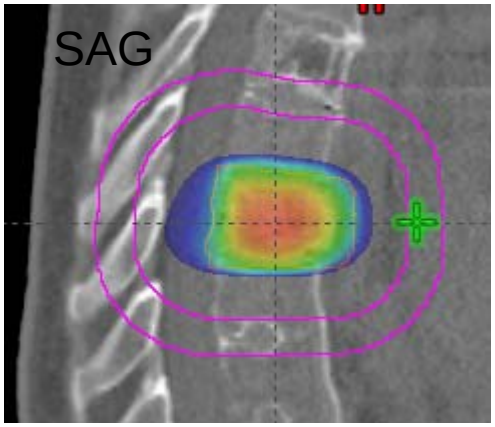



50% PD and Above

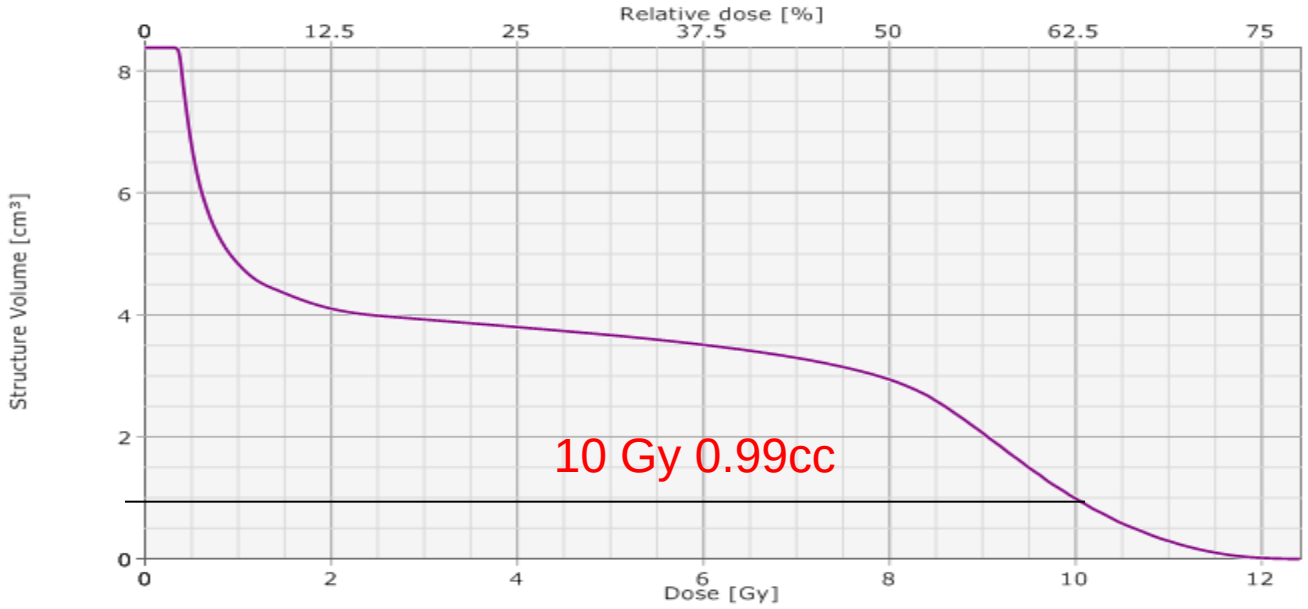
Sometimes difficult to meet $R_{50\%}$ and $D_{2cm}$ constraints if you use those constraints.

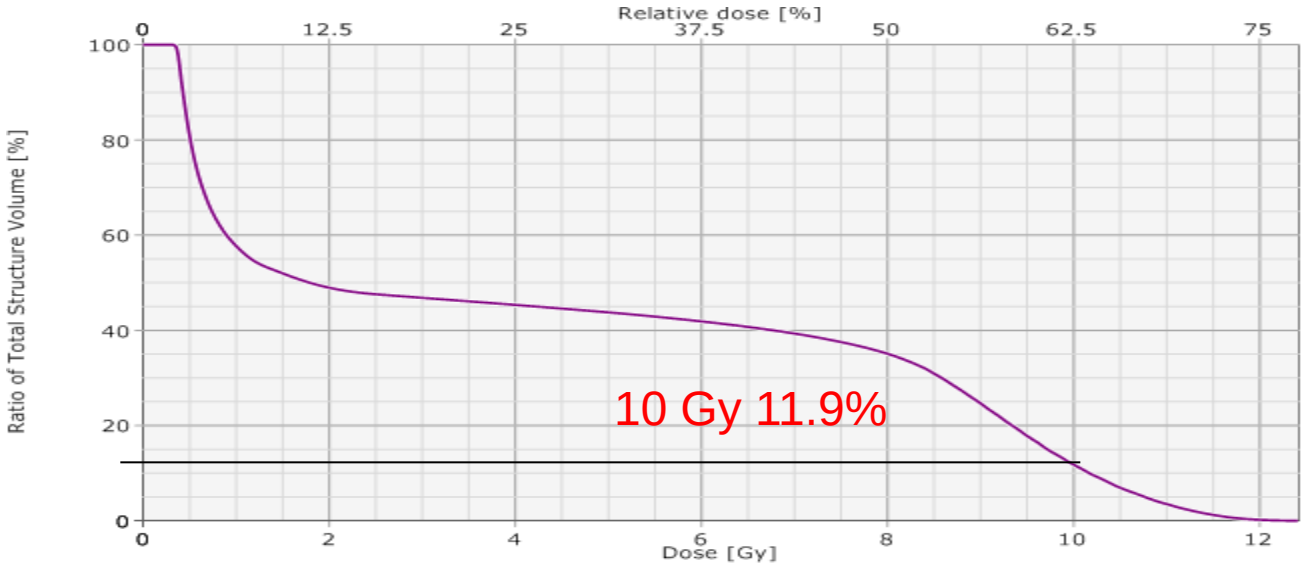
Cord:
Sometimes difficult to meet 10Gy constraints, even though max point dose 14Gy can be met.



# 9 Field IMRT: Cord Dose DVH




RTOG 0631 Criteria:

10 Gy covers <= 0.35cc
AND
10 Gy covers <= 10%
AND
14 Gy covers <= 0.03cc
(Montefiore
Max point dose 14Gy)

Max point cord dose:
12.4 Gy

# Montefiore-Einstein Cancer Center
# SBRT Registry Study

## Lung

*Peripheral Lesions*

- Three fractions: 60 Gy (20 Gy per fraction) (Based on RTOG 0618)

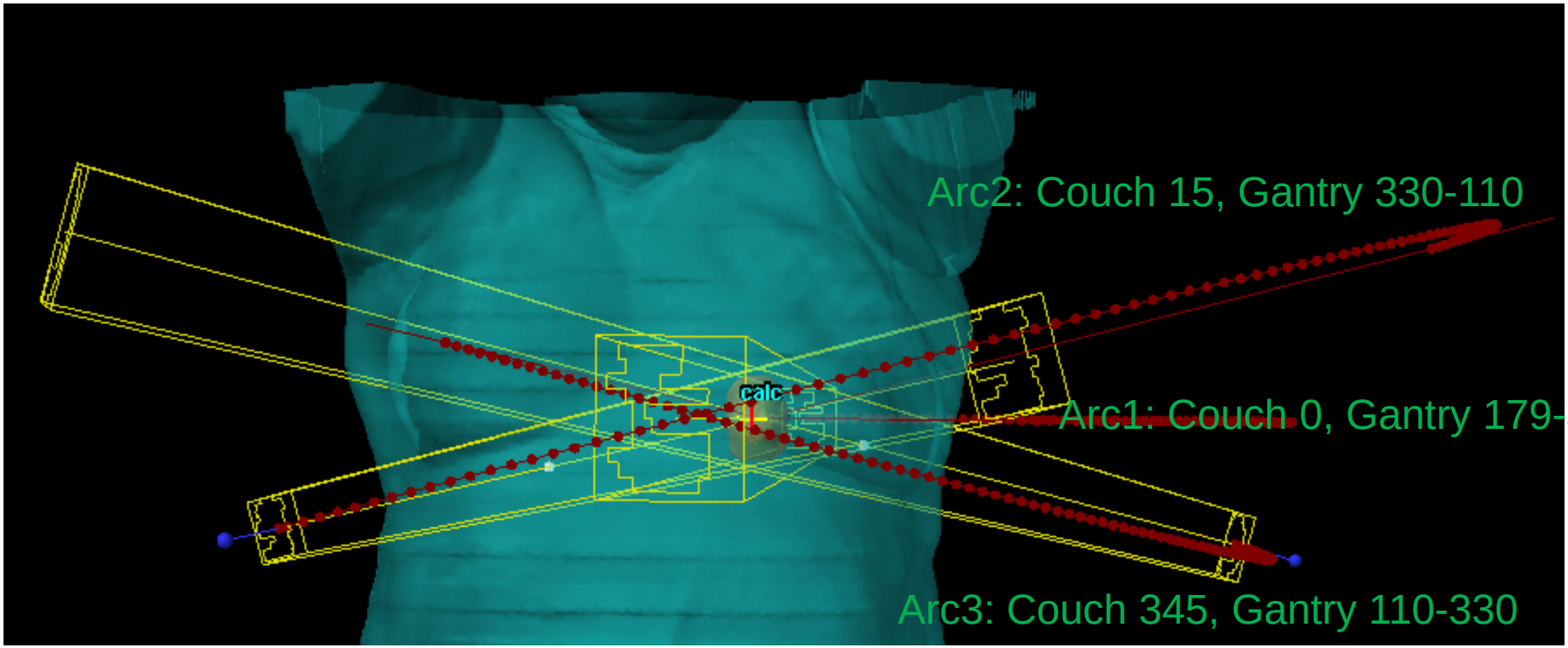
*Central Lesions*

- Five fractions: 50 Gy (10 Gy per fraction) (Based on RTOG 0813)

For Lung cases, it is often necessary to have non-coplanar beams to achieve fast dose fall off.

We use three partial arc VMAT technique
Each arc at least 100 degree
Non-coplanar couch angle up to 20 degree

Non-coplanar multiple IMRT or 3DCRT beams can be also used.




Arc 2 and Arc 3 are mostly anterior arcs to gain clearance

# MECC SBRT Registry: Lung

## Constraints

Three Fraction (20Gy x 3) (Based on dose of RTOG 0618):

**Heart:** Maximal point dose is 30 Gy (10 Gy per fraction)

**Ipsilateral brachial plexus**: Maximal point dose is 24 Gy (8 Gy per fraction)

**Spinal Cord**: Maximal point dose is 18 Gy (6 Gy per fraction)

**Esophagus:** Maximal point dose is 27 Gy (9 Gy per fraction).

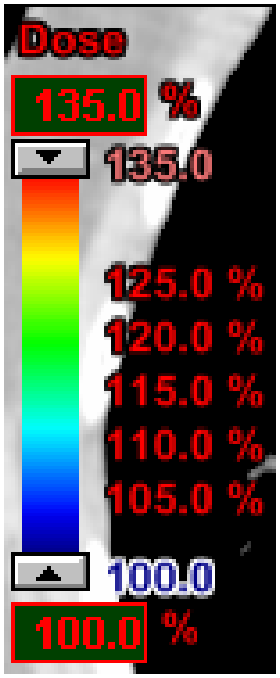
**Trachea/ipsilateral bronchus:** Maximal point dose is 30 Gy (10 Gy per fraction)

**Whole lung minus GTV:** V20<10%;

**Skin:** Maximal point dose is 24 Gy (8 Gy per fraction)

**Ribs:** Goal is 30cc of chest wall volume <30 Gy without compromising PTV coverage

## Prescription Isodose Surface Coverage:



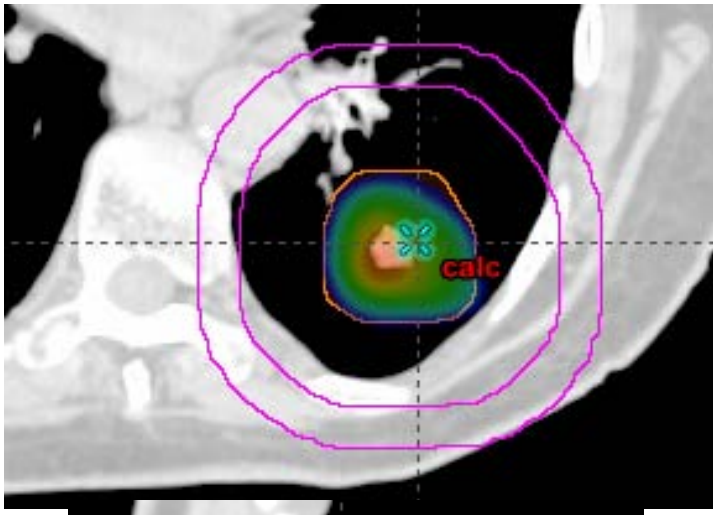

PD = 100% = 20 Gy/fx x 3

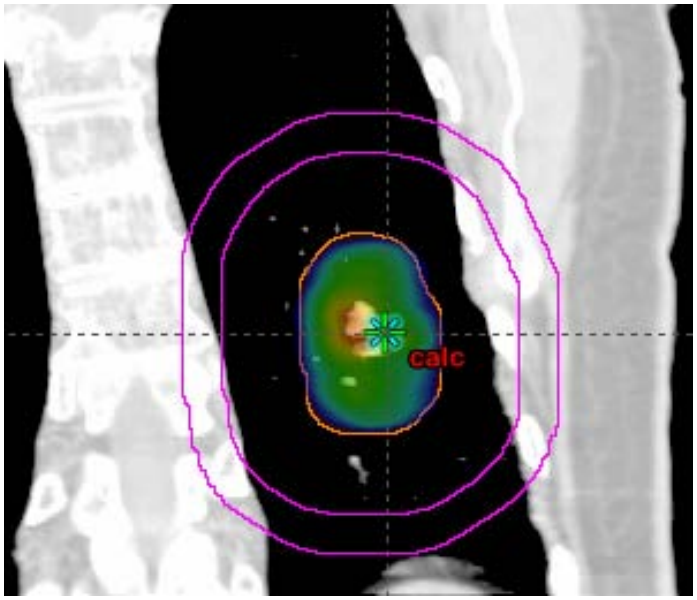
PTV V100 = 95%

PTV V100 = 95%

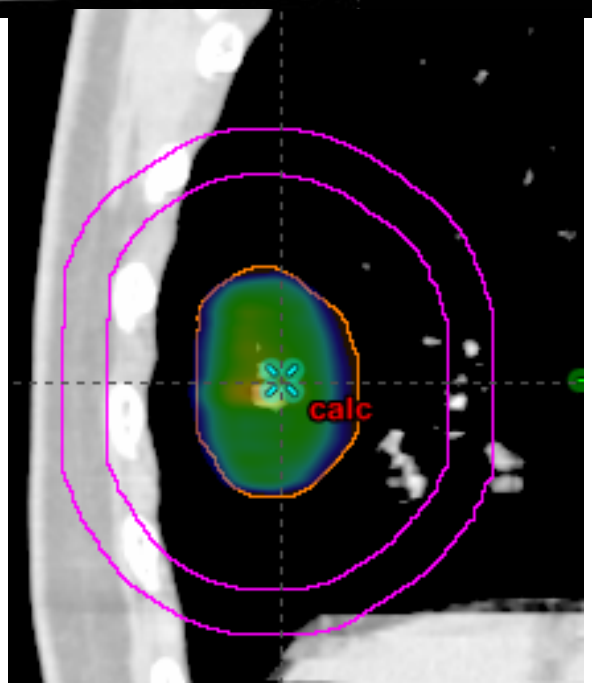
100% PD and Above

CAX




Cor

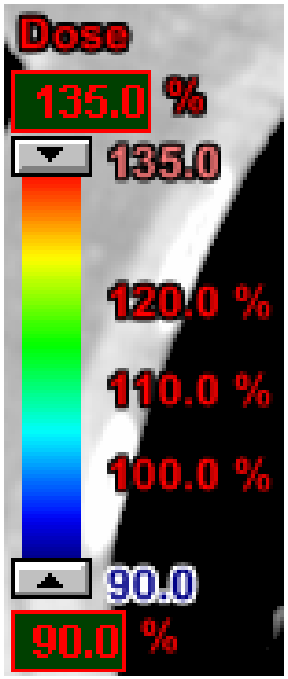



Sag

PTV

2cm-3cm ring

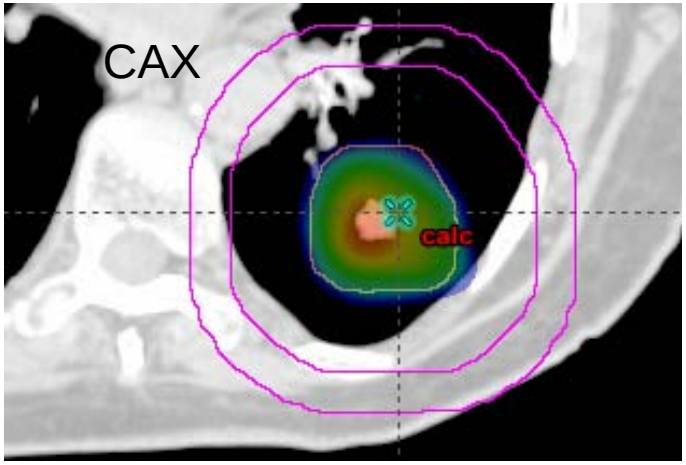
## Prescription Isodose Surface Coverage:



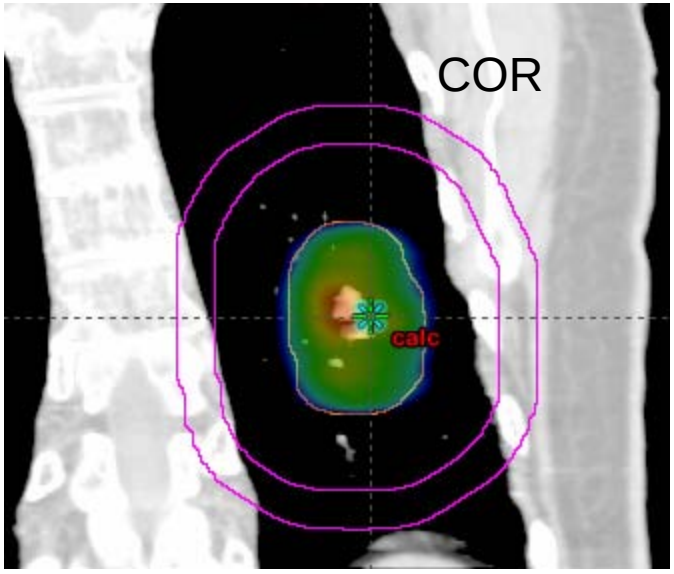

PD = 100% = 20 Gy/fx x 3

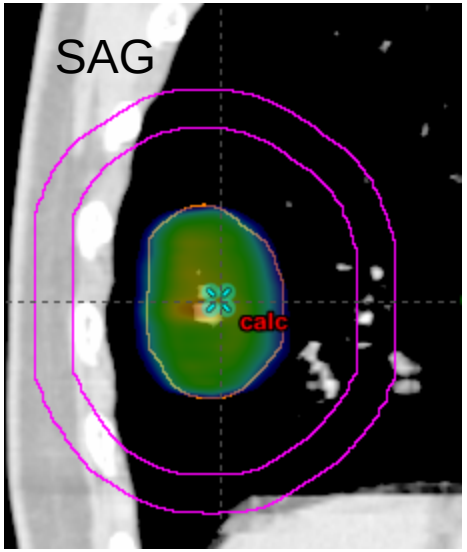
PTV V90% > 99%

Here PTV V90% = 100%




90% PD and Above

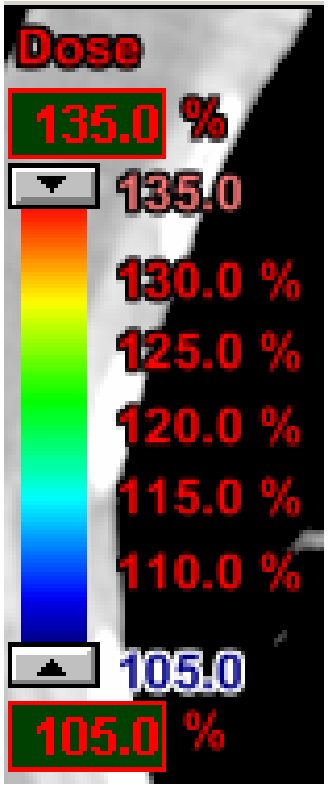



PTV

2cm-3cm ring

# High Dose Spillage



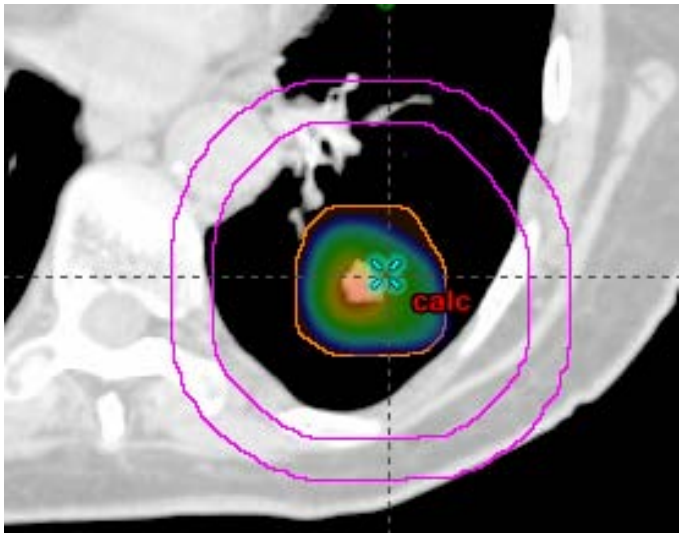

PD = 100% = 20 Gy/fx x 3

Max PTV dose = 135.0%

105% covered volumes outside of PTV <= 15% of volume of PTV

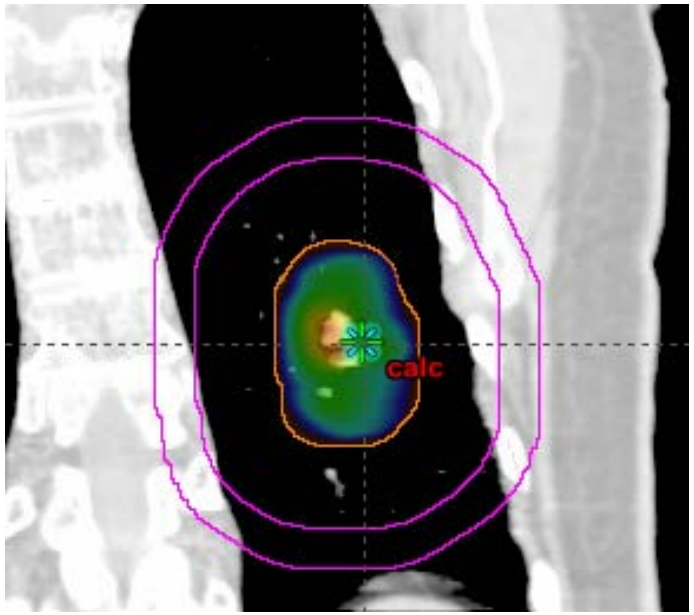
Here PTV = 40.2 cc

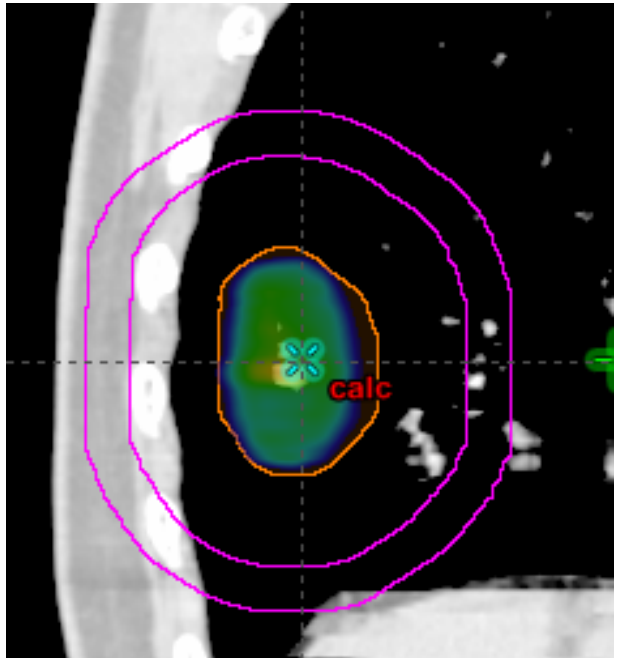
V105-PTV = 0.1 cc (0.2 %)




PTV

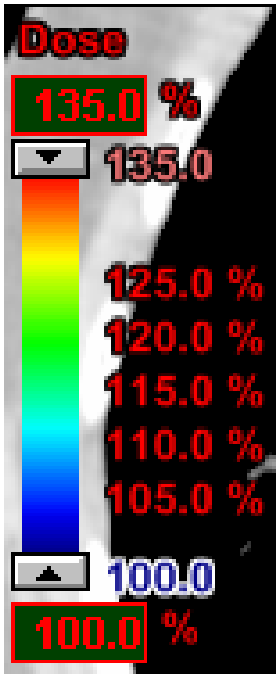
2cm-3cm ring




105% PD and Above

# Conformality : Prescription Dose Volume vs. PTV Volume

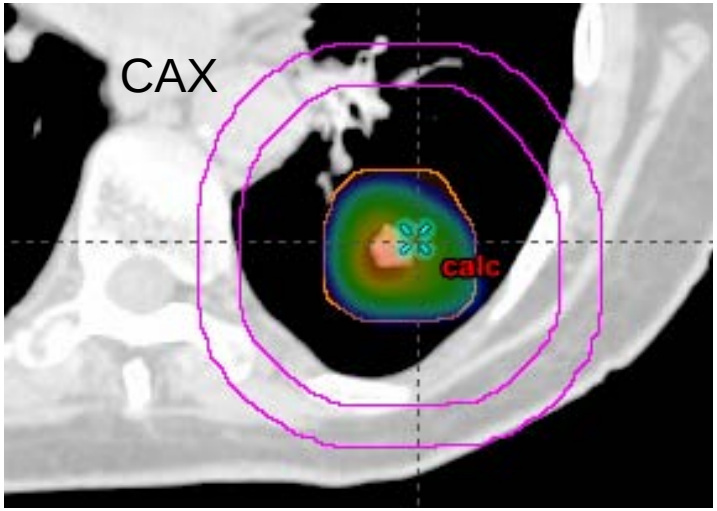


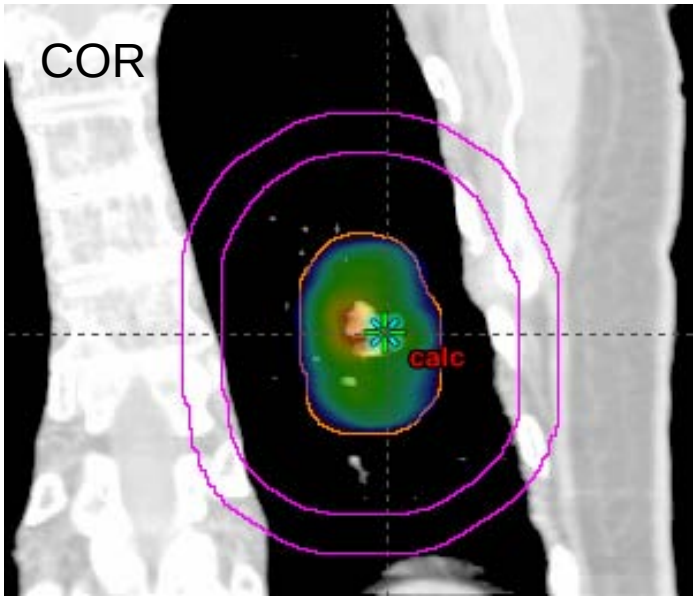

PD = 100% = 20 Gy/fx x 3

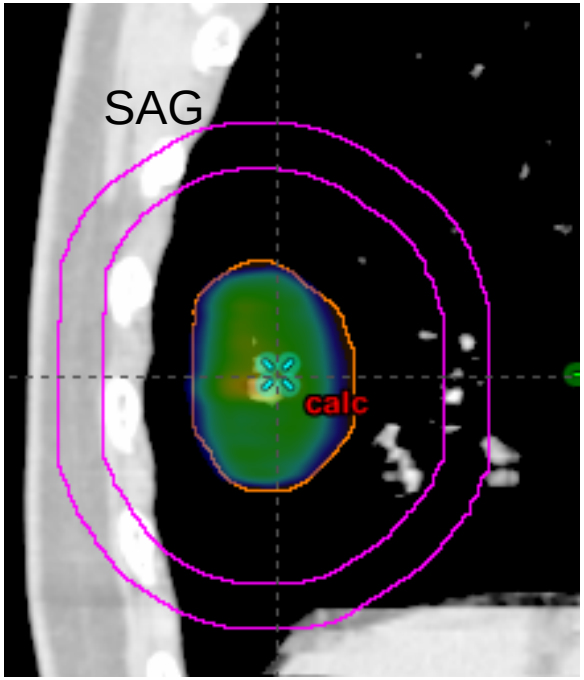
V100 / PTV volume <= 1.2

Here PTV = 40.2 cc
V100 = 41.0 cc
Ratio = 1.02

100% PD and Above



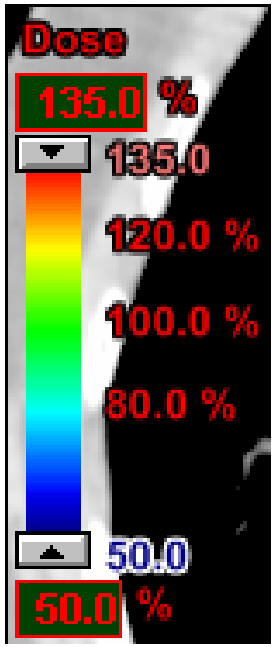




PTV

2cm-3cm ring

# Intermediate Dose Spillage: $R_{50\%}$ and $D_{2cm}$




For PTV = 40.2 cc

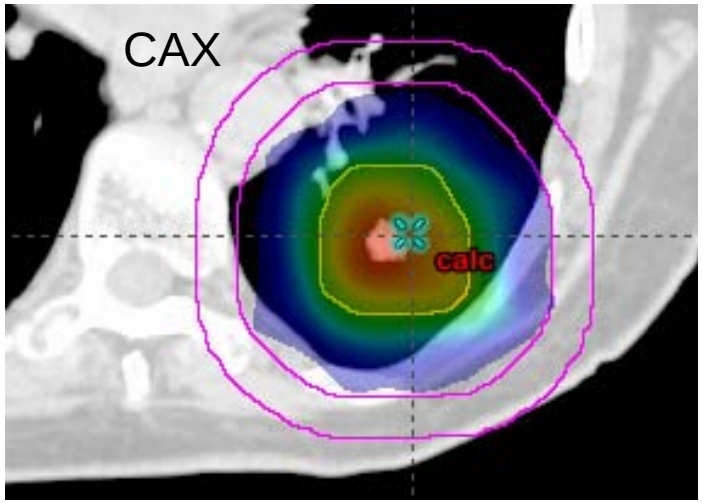
$R_{50\%}$ <= 4.2; $D_{2cm}$ = 59.6%

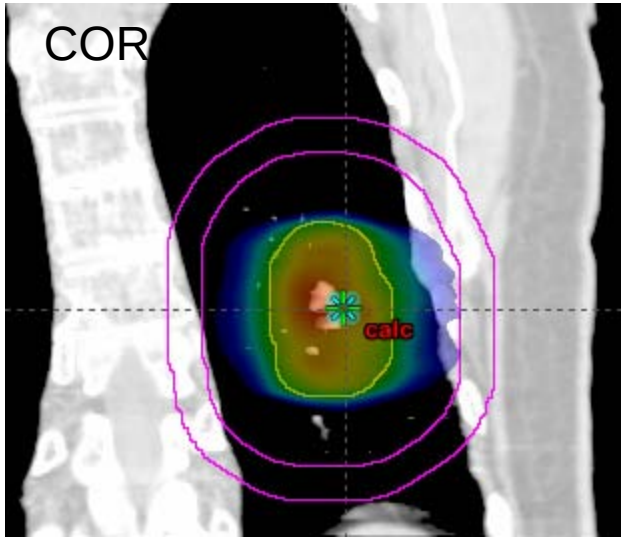
Here V50% = 169.5 cc

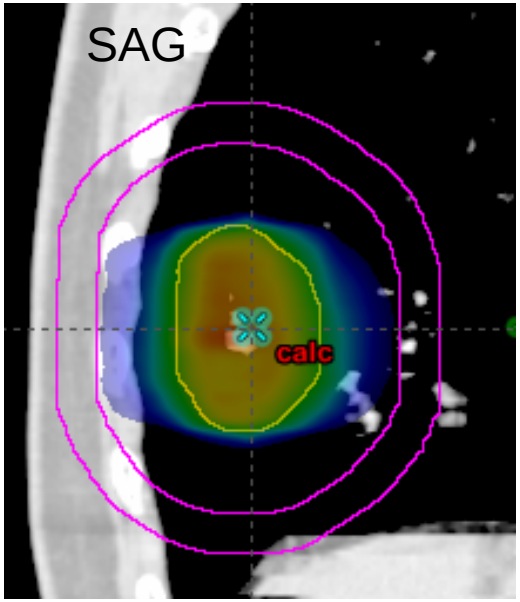
$R_{50\%}$ = 4.2

$D_{2cm}$ = 52.6%

50% PD and Above

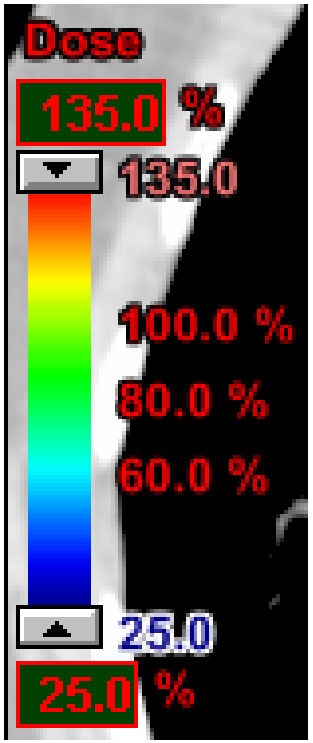


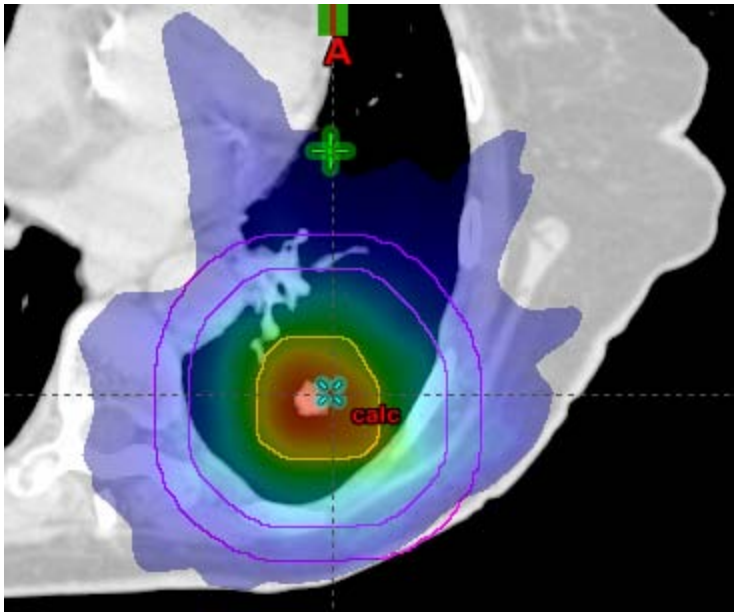




PTV

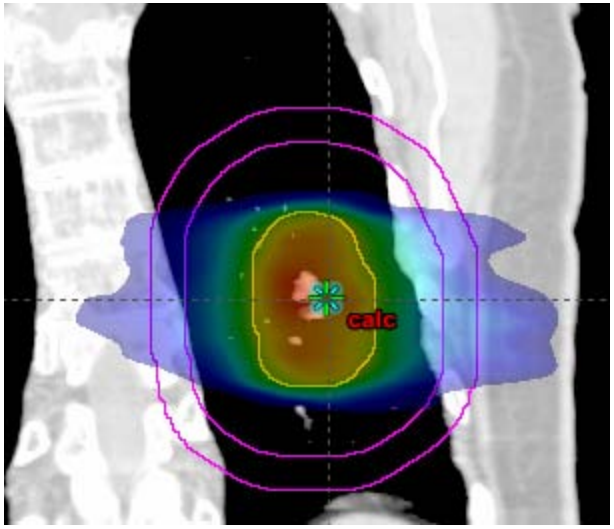
2cm-3cm ring

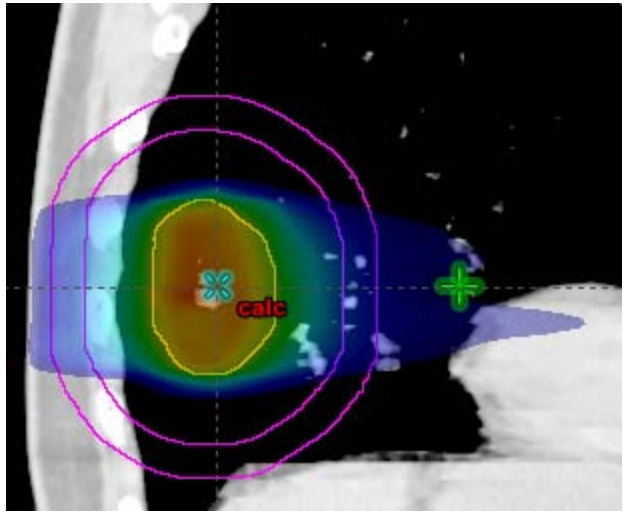



25% isodose restricted mainly in the ipsilateral lung



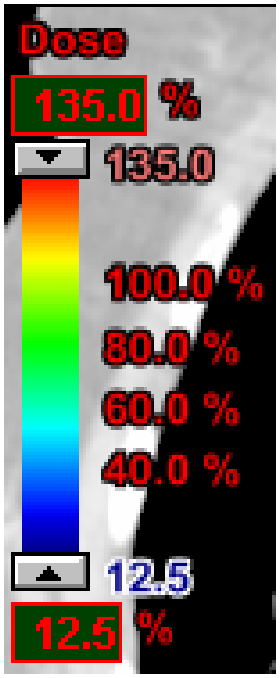

25% PD and Above



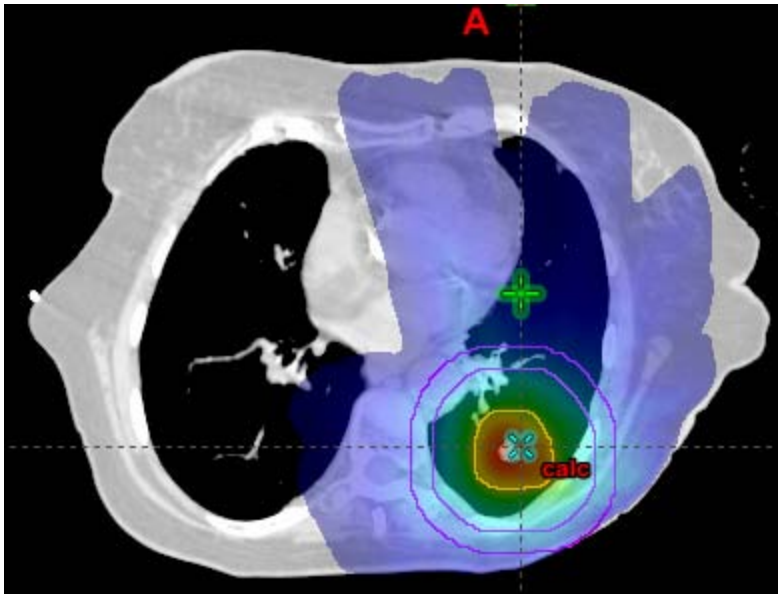




PTV

2cm-3cm ring



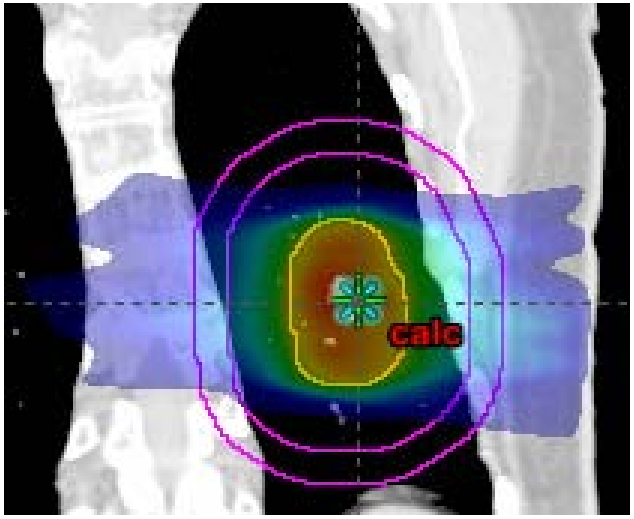

12.5% isodose restricted mainly in the ipsilateral lung

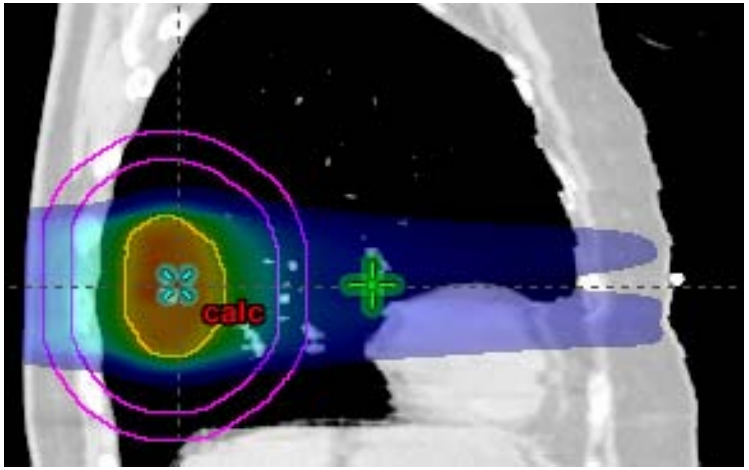



12.5% PD and Above

PTV

2cm-3cm ring



# MECC SBRT Registry: Lung

## Constraints

Five Fraction(10Gy x 5) Based on RTOG 0813:

**Heart:** <15cc receives ≥32 Gy (6.4 Gy/fx); maximum point dose ≤52.5 Gy

**Trachea/ipsilateral bronchus** (non-adjacent wall): <4 cc receives ≥18 Gy (3.6 Gy/fx); maximum point dose ≤52.5 Gy

**Great vessels** (non-adjacent wall): <10 cc receives >47 Gy (9.4 Gy per fraction); maximum point dose ≤52.5 Gy

**Ipsilateral brachial plexus**: <3 cc receives ≥ 30 Gy (6 Gy/fx); maximum point dose ≤32 Gy (6.4 Gy per fraction)

**Spinal Cord**:

<0.25 cc receives≥ 22.5 Gy (4.5 Gy/fx)

<0.5 cc receives≥ 13.5 Gy (2.7 Gy/fx)]

Maximal point dose is 30 Gy (6 Gy per fraction)

**Esophagus**: <5 cc receives ≥27.5 Gy (5.5 Gy per fraction); maximum point dose ≤52.5 Gy

**Whole lung minus GTV**:

<1500 cc receives ≥12.5 Gy (2.5 Gy per fraction)

<1000 cc receives ≥13.5 Gy (2.7 Gy per fraction)

**Skin**: <10 cc receives ≥30 Gy (6 Gy/fx). Maximal point dose is 32 Gy (6.4Gy per fraction)

Same beam arrangements/techniques can be used as peripherally located tumor.

# Montefiore-Einstein Cancer Center
# SBRT Registry Study

## Liver

### Metastasis

If lesions > 2cm from Porta Hepatis/Bile Duct: Three Fractions 20Gy x 3
If lesions ≤ 2cm from Porta Hepatis/Bile Duct: Five Fractions 10Gy x 5

### *HCC*

- Five fractions: 30-50 Gy (depends on $V_{eff}$)
- $V_{eff}$ Dose per fraction

| $V_{eff}$ | Dose per fraction |
|---|---|
| < 0.3 | 10 Gy x 5 |
| 0.3 - 0.4 | 9 Gy x 5 |
| 0.4 - 0.5 | 8 Gy x 5 |
| 0.5 - 0.6 | 6 Gy x 5 |

$$V_{eff} = \sum_i \Delta v_i \left( \frac{d_i}{d_{ref}} \right)$$

Dawson LA et al Acta Oncol 45:856, 2006

Same beam arrangements/techniques can be used as lung SBRT.

# MECC SBRT Registry: Liver
## Constraints

**Metastasis**

If lesions > 2cm from Porta Hepatis/Bile Duct: Three Fractions 20Gy x 3

If lesions ≤ 2cm from Porta Hepatis/Bile Duct: Five Fractions 10Gy x 5

**Liver minus-GTV**: >700mL receive <15 Gy

**Heart:** <15cc receives ≥32 Gy; maximum point dose ≤52.5 Gy

**Lung:** <1000 cc receives ≥11.4 Gy (3.8 Gy/fx)

**Esophagus**: Maximal point dose is 27 Gy (9 Gy per fraction)

**Stomach/Duodenum/Small Bowel**: Maximal point dose 30 Gy

**Kidney:** ≤1/3 volume (sum of left and right) receives ≥15 Gy; V6 < 10%

**Colon/Rectum**: Maximal dose 34 Gy to 0.5 cc

**Spinal Cord**: Maximal point dose is 18 Gy (6 Gy per fraction)

**Skin**: Maximal point dose is 24 Gy (8 Gy per fraction)

# MECC SBRT Registry: Liver

## Constraints

**Hepatocellular Carcinoma**

Five Fractions

- Normal Liver: defined as liver minus GTV
  - ≥ 700 cc liver volume must be outside of the PTV
  - Mean liver-GTV dose < 18 Gy
- Heart: Maximal dose in 40 Gy to 0.1 cc.
- Kidney: For patients with only one functioning kidney (as demonstrated by renal scan) or when one kidney is irradiated to mean dose >12 Gy:
  - > 80% of the opposite kidney must receive <12 Gy and volume receiving 6 Gy (V6) must be <10%.
  - Ideally 2/3 of the combined kidney volume will receive < 15 Gy
- Spinal Cord: Maximal dose is 27 Gy to 0.1 cc.
- Duodenum: Maximal dose is 30 Gy to 0.5 cc.
- Small Bowel: Maximal dose is 30 Gy to 0.5 cc.
- Stomach: Maximal dose is 30 Gy to 0.5 cc.
- Large bowel: Maximal dose is 34 Gy to 0.5 cc.
- Esophagus: Maximal permitted dose is 30 Gy to 0.5 cc.
- Rib: Maximal point dose is 54 Gy.
- Liver capsule (5 mm within outer contour): Maximal point dose is 54 Gy.
- Skin (surface rim of 5 mm): Maximal point dose is 48 Gy.

**Stereotactic body radiation therapy:**

**The report of AAPM Task Group 101**

Stanley H. Benedict et al

**Med. Phys. 37 (8), August 2010**

**Detailed information about SBRT**

# SBRT CT simulation

- For upper thoracic regions, both arms (elbows) should be over the patient's head and included in the CT scan so that clearance of beams can be visualized during planning.
- Scan 15 cm beyond field borders (sometimes non-coplanar beams are needed).
- For spine cases, include sacrum for lower spine or include C1 for upper spine so that vertebrae can be easily identified.

# SBRT C-Spine

- CT scan has to include C1
- Setup uncertainty large due to flexibility in neck area
- Fusion with MRI might be difficult because of different neck position
- 2-3mm margin should be added for PTV
- Hypofractionation preferred instead of single fraction – *unless significant cord clearance*
- We use BlueBAG™ with vacuum suction plus head and neck mask as immobilization device

# SBRT T-Spine

- CT scan has to either include C1 or L Spine
- Arms on the side preferred so that patient can stay comfortable
- Beams avoid arms
- We use BlueBAG™ with vacuum suction as immobilization device

# SBRT L-Spine

- CT has to include Sacrum
- Arms on chest instead of up for comfort
- We use BlueBAG™ with vacuum suction as immobilization device

# SBRT Lung/Liver/Abdominal Cases

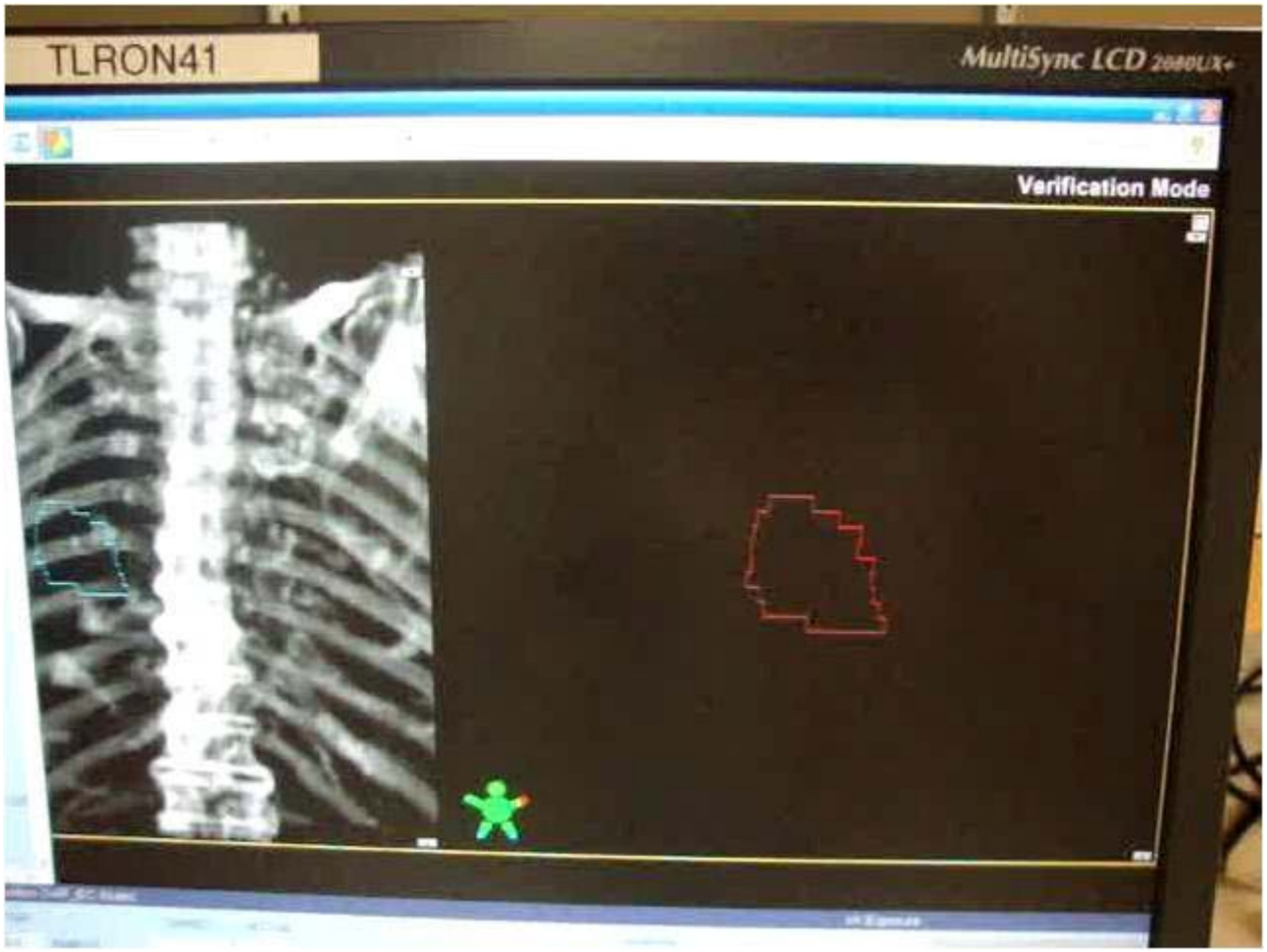
- 4DCT simulation must be done first to access tumor motion range
- Gating will be considered only if motion > 0.5cm, and the patient has a regular, reproducible breathing pattern; alternatively, an ITV can be created.
- For gating cases, BlueBAG™ without vacuum suction is used as immobilization device.
- Abdominal Belt Compression system can be used for some patients
- Fiducials necessary for Liver/Abdominal Cases: no other way to visualize tumor. CBCT image quality, FOV limitation for lateral tumors.
- If no fiducials for Lung cases, Fluoro on the machine must be done before simulation to verify visualization of tumor

# SBRT Lung/Liver/Abdominal Cases

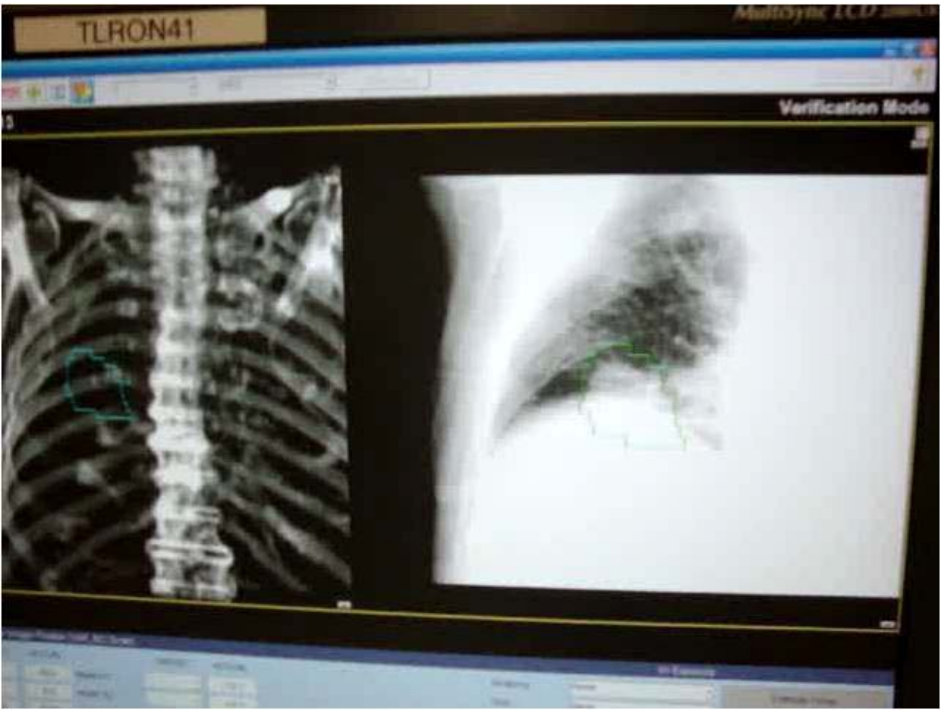
- If non-gating, may consider one or both arms on the side. Non-coplanar beams could be used to compensate for lateral beams. If gating is used, only coplanar beams can be used for some machines, arms on the side could further limits beams.
- VMAT is a good option (can not be combined with gating for many machines)
- Gating + fixed beam IMRT or EDW is not advisable (takes way too long to deliver), use FIF instead if you must.
- Beam arrangement should consider collision possibility for lateral tumors. Keep beams /arcs on the ipsilateral side.

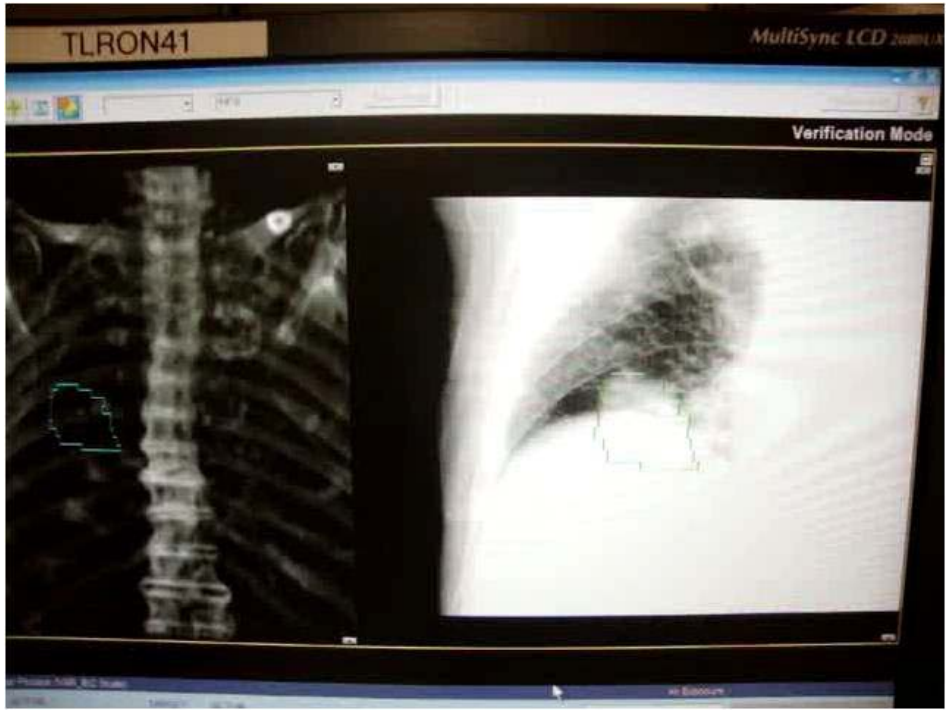
# SBRT Lung/Liver/Abdominal Cases

- If no fiducials, create fluoro beam aperture that hugs GTV.
- If there is fiducials, create fluoro beam aperture that use fiducials as corners.
- CBCT alignment with GTV, bony landmark secondary but should be less than 1cm discrepancy. Otherwise, reposition patient.
- CBCT sometimes do not align well with average sim CT due to breathing variation
- Fluoro to verify positioning after CBCT.
- Fluoro between fields to monitor setup consistency.



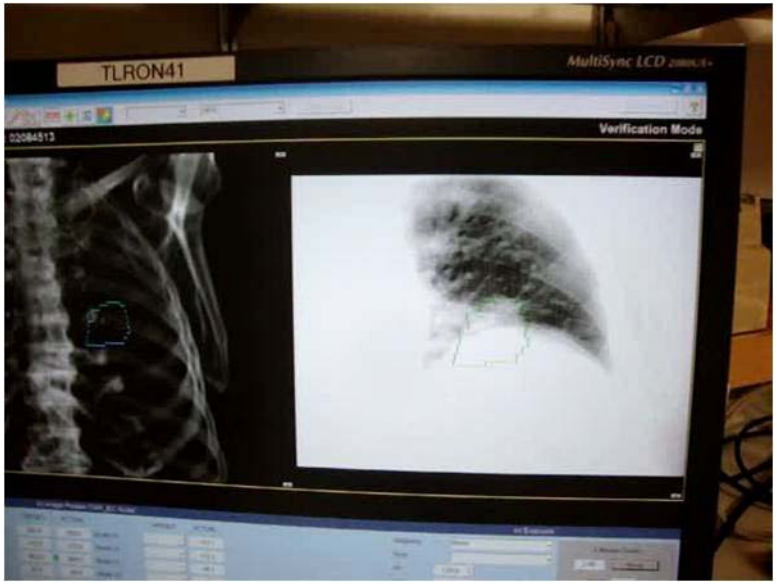

Under fluoro: only the MLC shape outline (hugs GTV) will be visible on screen
When the shape turns green, beam is on.
GTV is visible on screen when fluoro is on.
Our goal is to for GTV to match MLC shape when beam is on.




After 5mm superior shift.

GTV is 5mm too inferior (MLC acts as a scale). CBCT was done with free breathing (non-gated), therapist did not align superior part of CBCT with Gated CTsim tumor during image fusion.




At one different angle During treatment (a Total of 3 was done during treatment).

# Bottom line for SBRT

- Without an approved plan in the patient's chart, no treatment verification can be done. Physics must be present for treatment verification.
- If IMRT, without IMRT QA documented, no 1st treatment should be done.
- Attending must be present for every treatment fraction. Physics should be available for every treatment.

# What is a ‘Dry Run’?

- Treatment verification
  - Reproduce setup
  - Verify isocenter
  - Clinically mode up each treatment field
    - ➢ Check beam clearance (collision)
    - ➢ Check any interlock
      - ✓ MLC interlock? Reinitialized but can not clear means corruption of MLC files→ undeliverable beam
      - ✓ Potential MU problem? For example > 1000 for any single field beyond machine capability for non-SRS beams

Clearly mark immobilization devices after successful dry run.

# Summary

- RTOG protocols are useful guidelines for treatment planning for SBRT
- SBRT procedures from CT simulation to treatment planning to treatment verification and treatment warrant serious attention from everyone involved. Establishing clear protocols for your own institution is necessary for the safe delivery of SBRT.

# Acknowledgements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