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RapidArc for SRT

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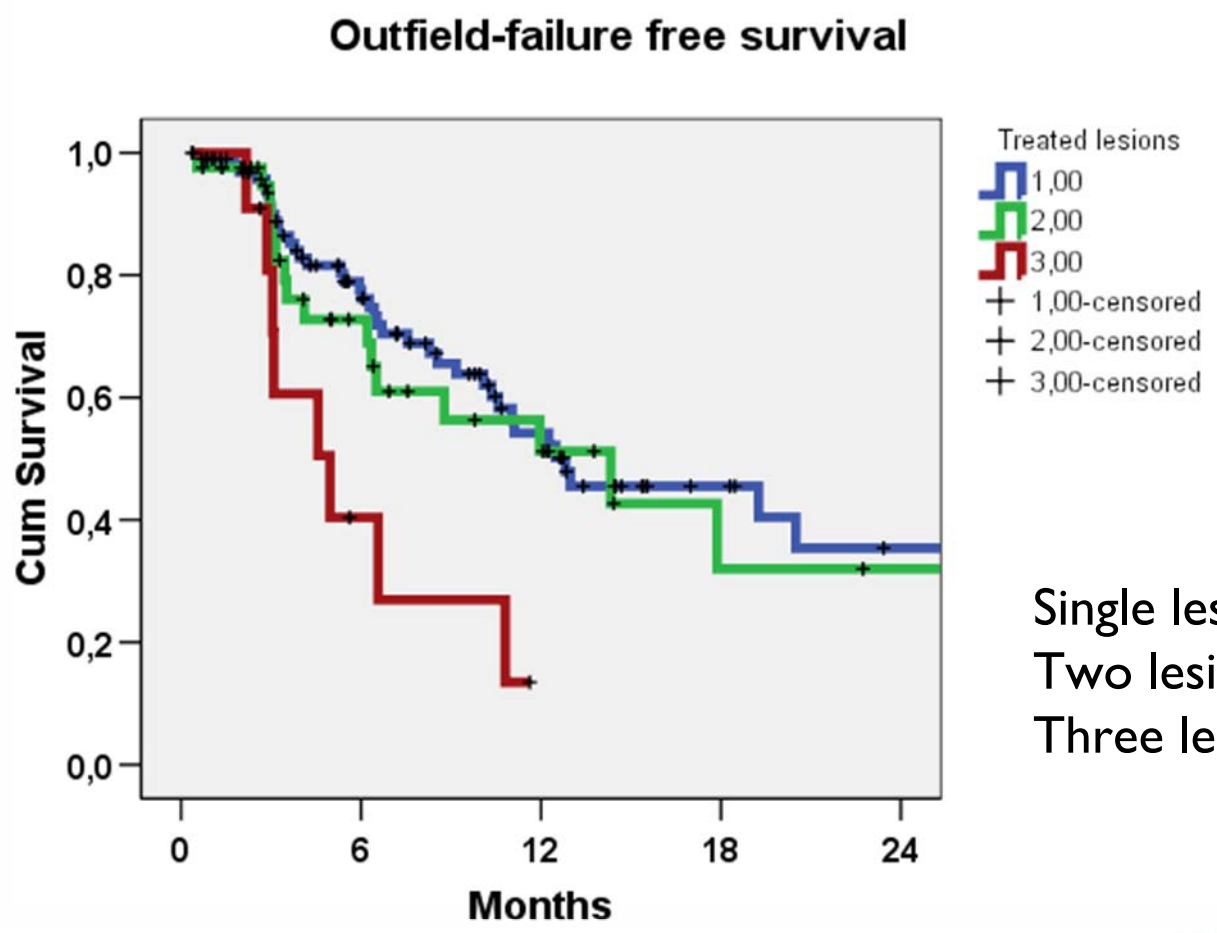
RapidArc for SBRT: Overview

- SRT for multiple brain metastases
  - Rationale for WBRT + simultaneous integrated boost
  - RapidArc optimization, dose measurement and delivery

- SBRT in lung
  - Rationale for faster delivery; dose prescription
  - RapidArc plan optimization
    - Problems of different dose engines
    - Constraint sets, including contralateral lung doses
  - Dosimetry
    - Measurements compared with calculations
    - Interplay effect between moving leaves and moving target

VUmc Why add WBRT for 3 brain metastases?

Out-field metastases after SRT in patients presenting with 1-3 metastases [VUMC, unpublished]



Single lesion: N=156 (63%)
Two lesions: N= 69 (28%)
Three lesions: N= 21 (9%)

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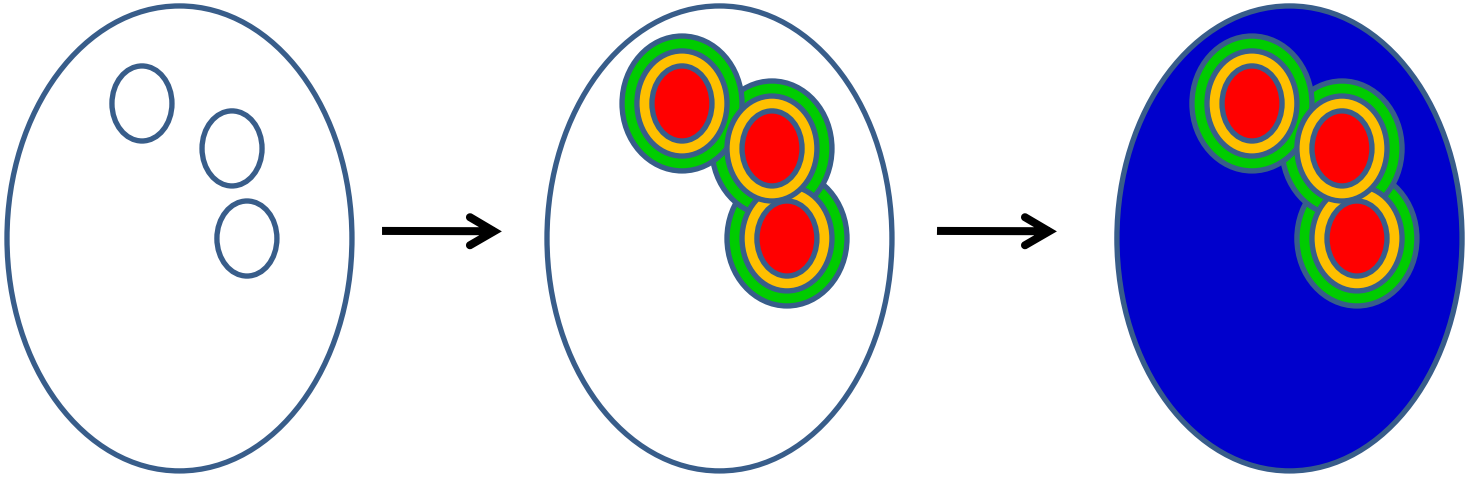
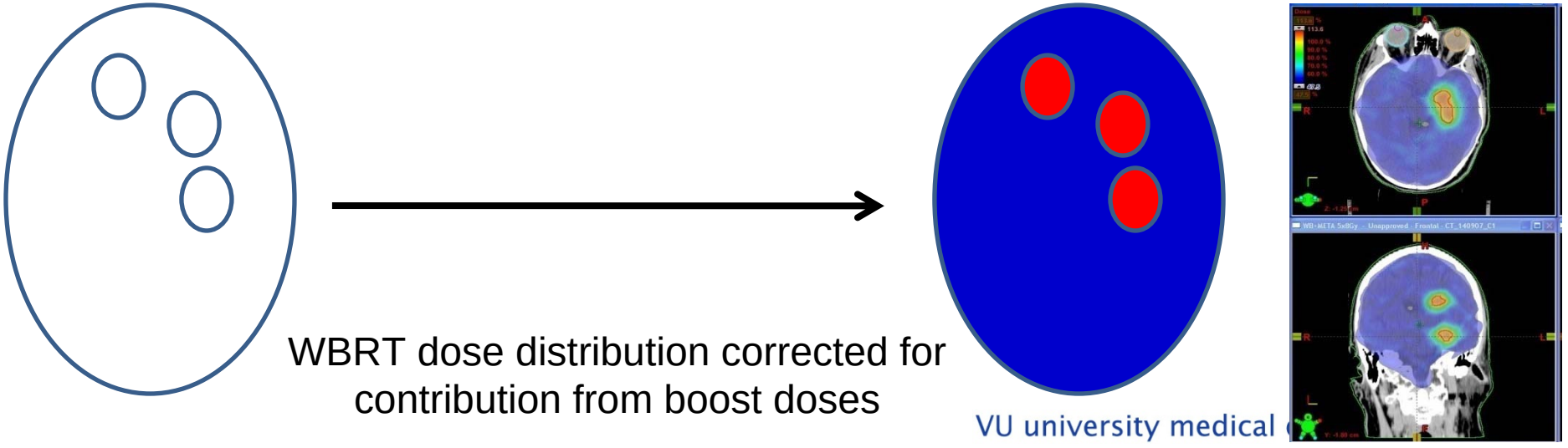
VUmc Approaches for combining WBRT and SRT



RapidArc WBRT with SIB



WBRT dose distribution corrected for contribution from boost doses

Risks of combining WBRT and SRT

Chang EL, 2009: Patients treated with SRT plus WBRT in a randomized trial were at greater risk of significant decline in learning and memory function by 4 months compared with the group receiving SRT alone.

Lagerwaard F, 2009

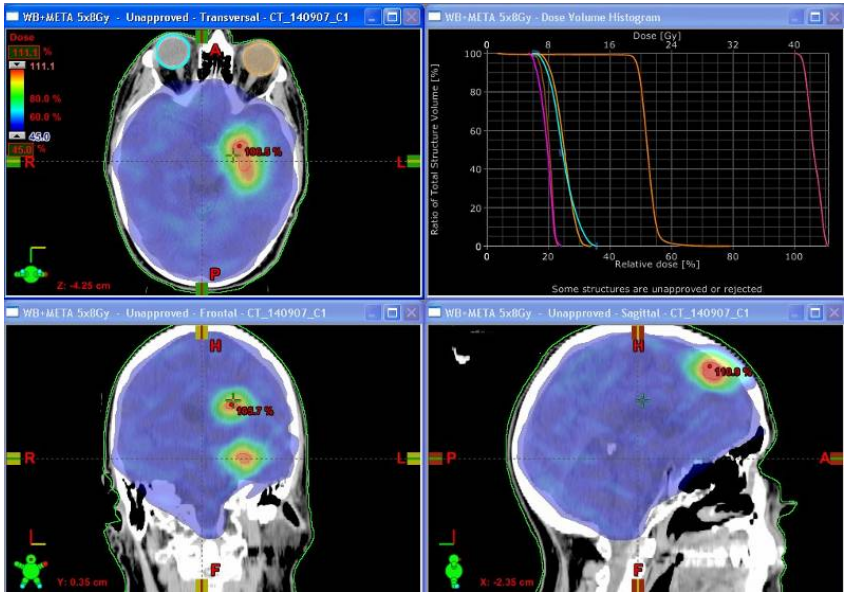
Rapid dose fall-off around SIB

Homogeneous whole brain dose

(avoid hot spots)

WBRT = 5x4 Gy

Sim. Integrated Boost = 5x8 Gy



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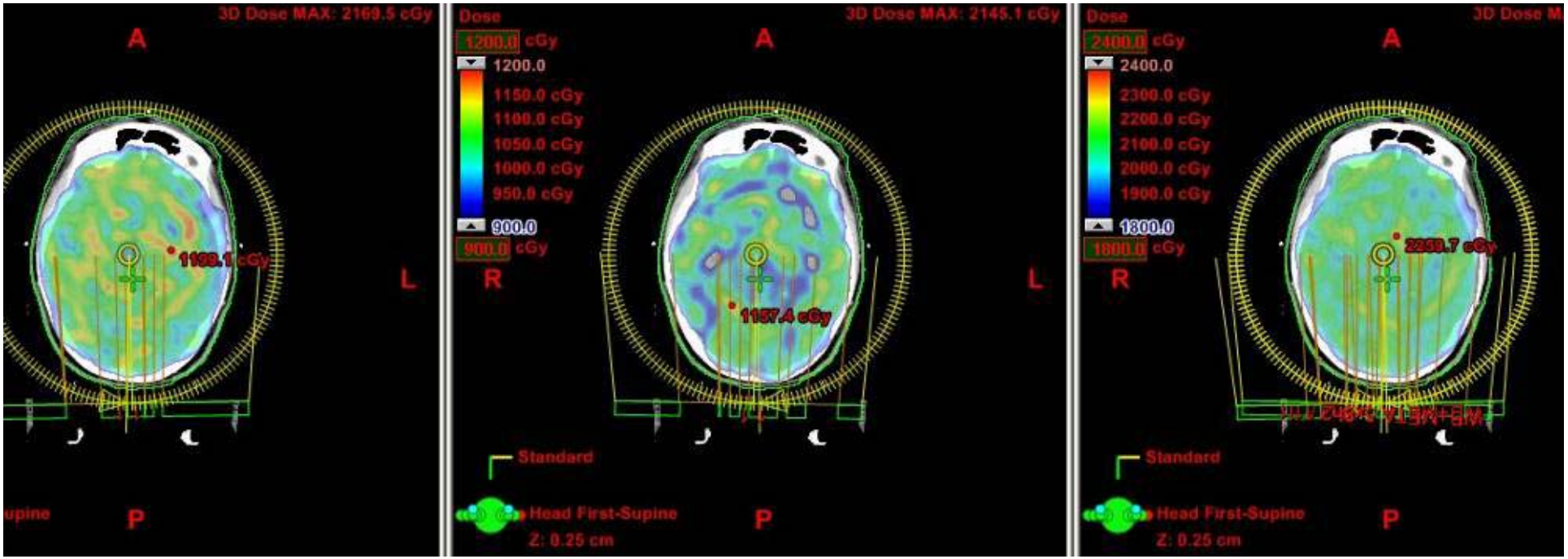
RapidArc: routine use of 2 arc delivery

(Lagerwaard F, 2009)



1st arc | 2nd compensatory arc | Dose summation

2 arcs delivery results in a more homogeneous dose distribution

RA delivery times < 3 minutes

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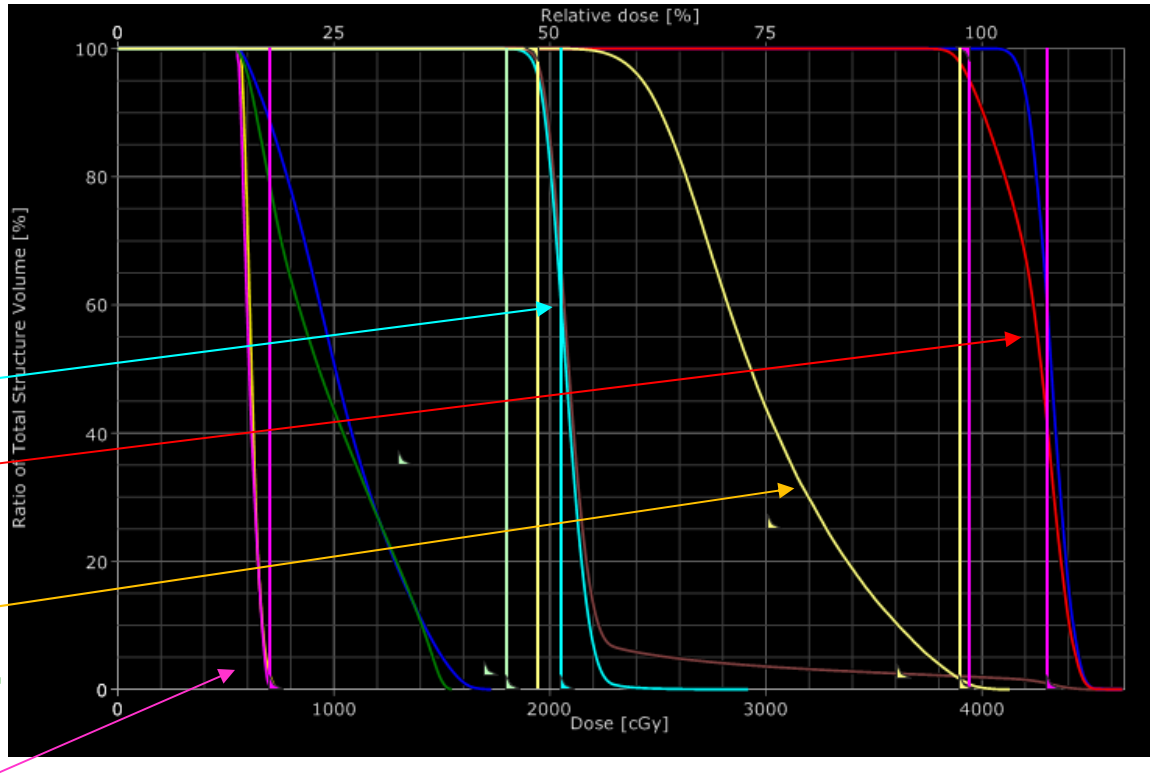
WBRT + SIB for brain mets

RapidArc optimization



Constraints on

- WBRT-ring-boost
- Boost PTVs
- Ring around boost
- Ring around WBRT
- Eye lens < 7 Gy
- WBRT-ring-boost V_{22Gy} < 10%
- Boost dose 38 - 45 Gy (95%-114%)

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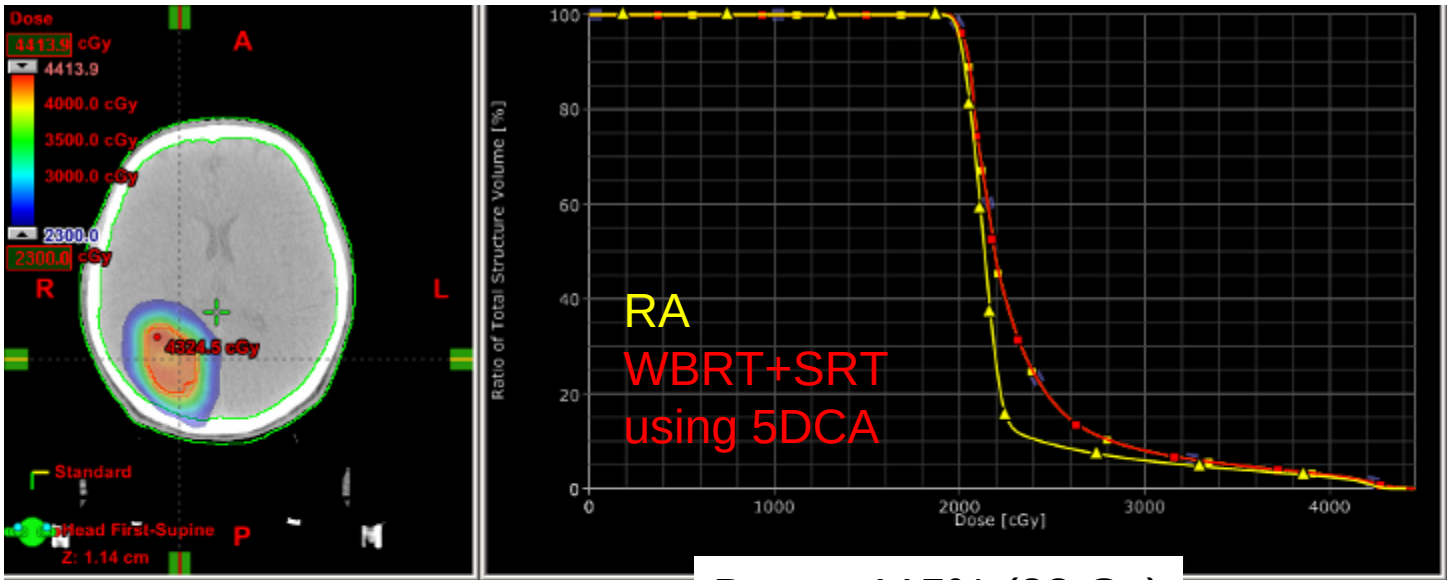
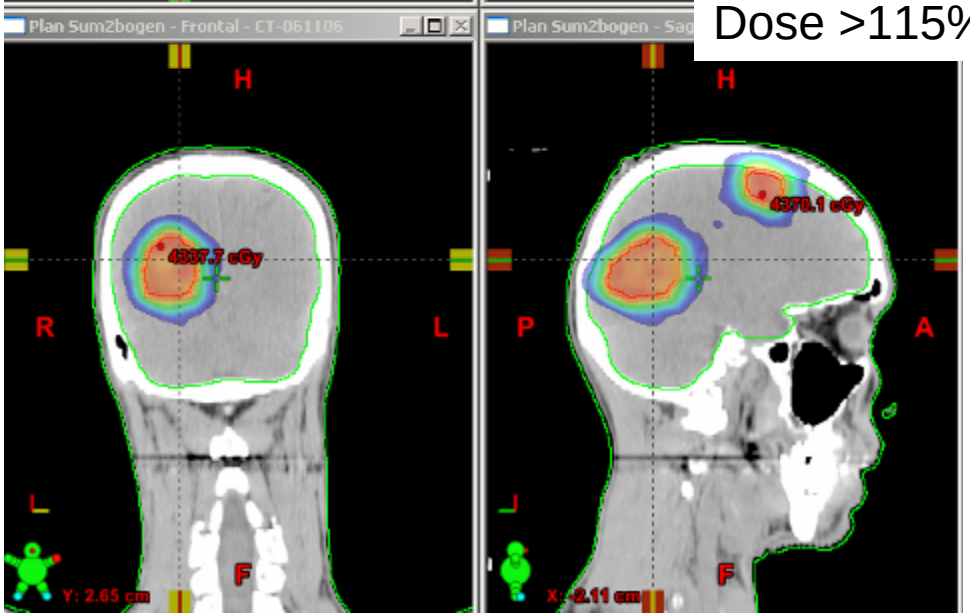
WBRT + SIB for brain mets

RapidArc vs conventional sequential boost



Dose >115% (23 Gy)



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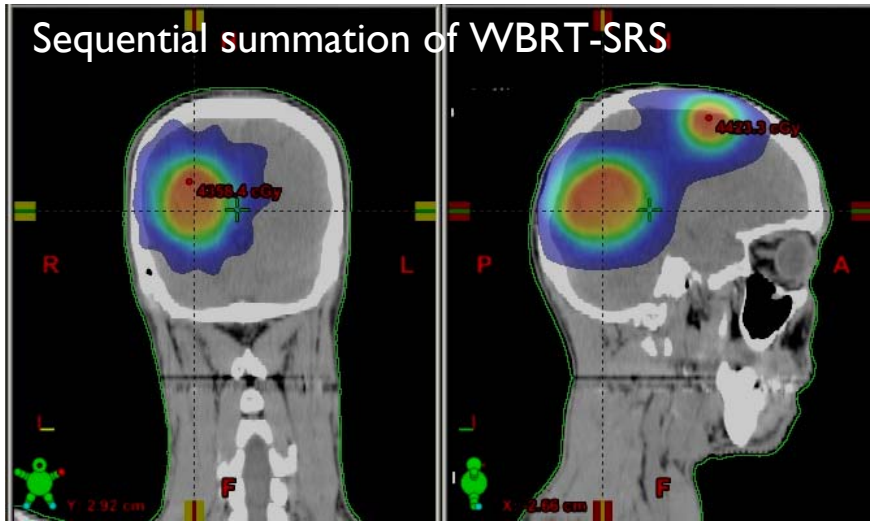
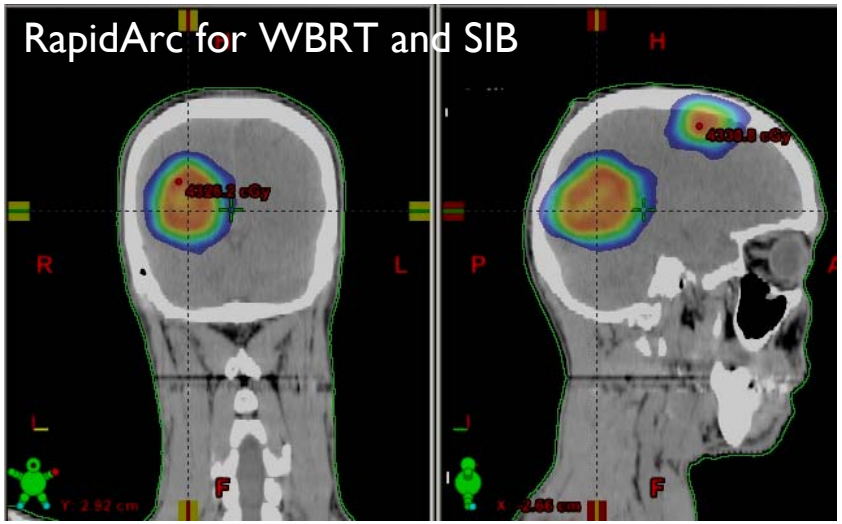
Benefits of using RapidArc for SIB

Improves dose gradients outside the metastases





- **Conventional treatment times ***
  - WBRT — 5x10=50 minutes
  - SRS (3 metastases) — 90 minutes
  - TOTAL TIME — 140 minutes
- **RapidArc treatment times**
  - WBRT + Integrated boost — 5x15=75 minutes

* *All times including online image guided setup*

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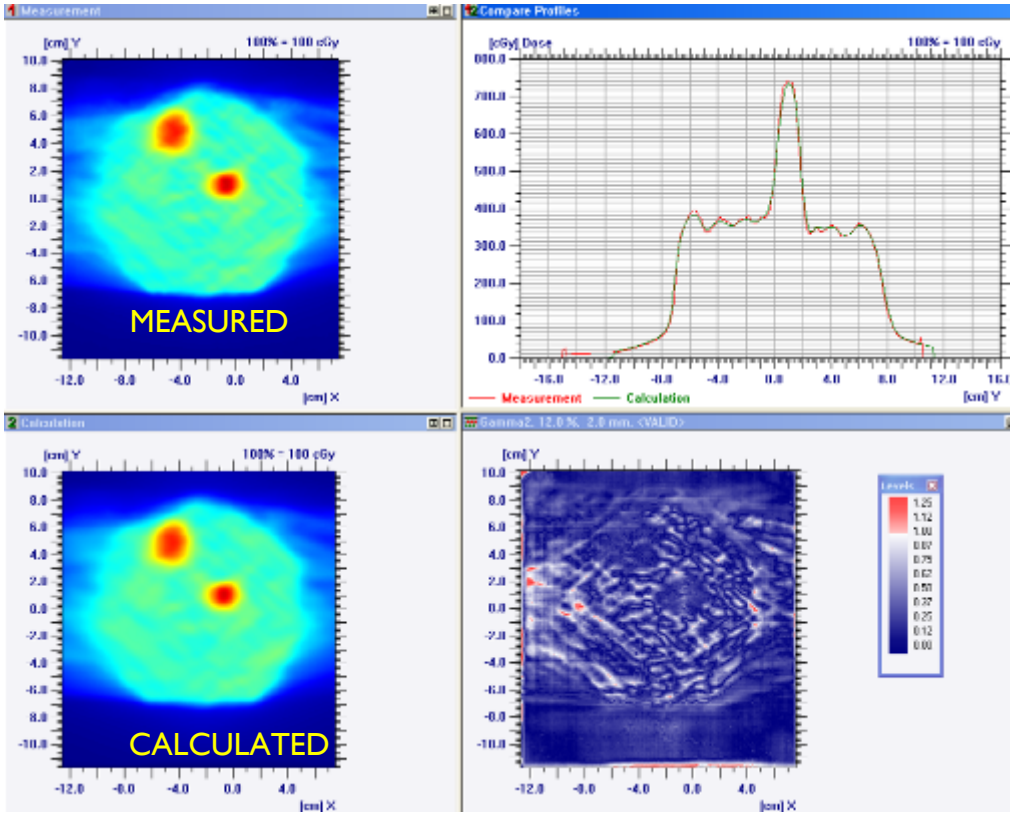
RapidArc + SIB: Dosimetry

- Use of 2 arcs = better agreement between measurements and calculations (Verbakel, 2009; Lagerwaard, *2009)*
  - *AAA does not accurately calculate dose modulation*
  - *2nd arc compensates for modulation of the first arc*
- Gafchromic EBT-I film, Gamma 3% - 2 mm

No. of pixels exceeding gamma criteria	<1%	1-2%	2-5%	>5%
Number of patients	5	5	4	0

Total gamma > 1	1.6%
Average gamma	0.34



Does RapidArc improve clinical outcomes?

Preliminary analysis in 40 patients (Lagerwaard F, unpublished)

Should preferably be restricted to patients with a good perfomance score (PS)

Number of metastases (3-5) and their volume (<20-25cc) appears to be less important than PS

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Conventional SBRT for lung

Very low toxicity [Lagerwaard F, 2008]

- Pneumonitis = 3.5%, rib fractures = 2%, chest pain =5%

Disadvantage of 8-12 static non-coplanar beams

- Delivery times (minus setup) of 10 – 16 min
- > 25% require repositioning during treatment
- Limited conformality for larger and irregular tumors

Speed has great impact in stereotactic RT !

- Improved patient comfort
- Stability of patient set-up and tumor position
- Utilization of personnel & equipment
- Potential radiobiological effects of longer treatments

Lung SBRT using RapidArc

- 200 patients treated since Sept 2008

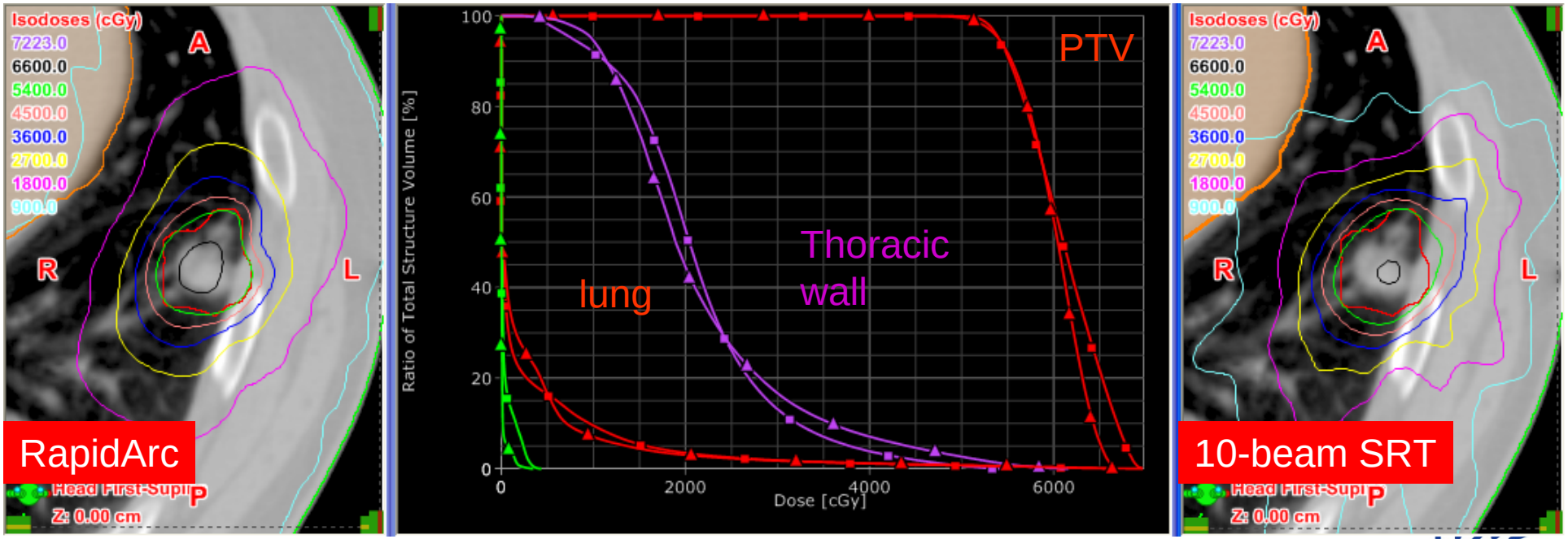
- Three 'risk-adapted' fractionation schemes
  - 3 x 18 Gy or 5 x 11 Gy or 8 x 7.5 Gy at 80% (95% of PTV)
  - PTV = ITV encompassing all motion + 5 mm margin
  - Dose prescription, OAR doses [*ROSEL study, Hurkmans 2009*]
  - D_{max} in PTV up to 140% of prescription

- CBCT based setup on PTV

Verbakel W, 2009

RA versus conv. SBRT: planning study

- 15 RapidArc cases replanned using 10 static non-coplanar beams
- CI_{80} and CI_{60} superior for RapidArc plans
- Chest wall receiving ≥45 Gy lower for RapidArc plans
- *Current constraint for contralateral lung (V5 <25%)*
- Delivery time (1000 MU/min): 3 min (7.5 Gy) – 6.5 min(18 Gy)
  Conv. SBRT delivery times averaged 11.6 minutes

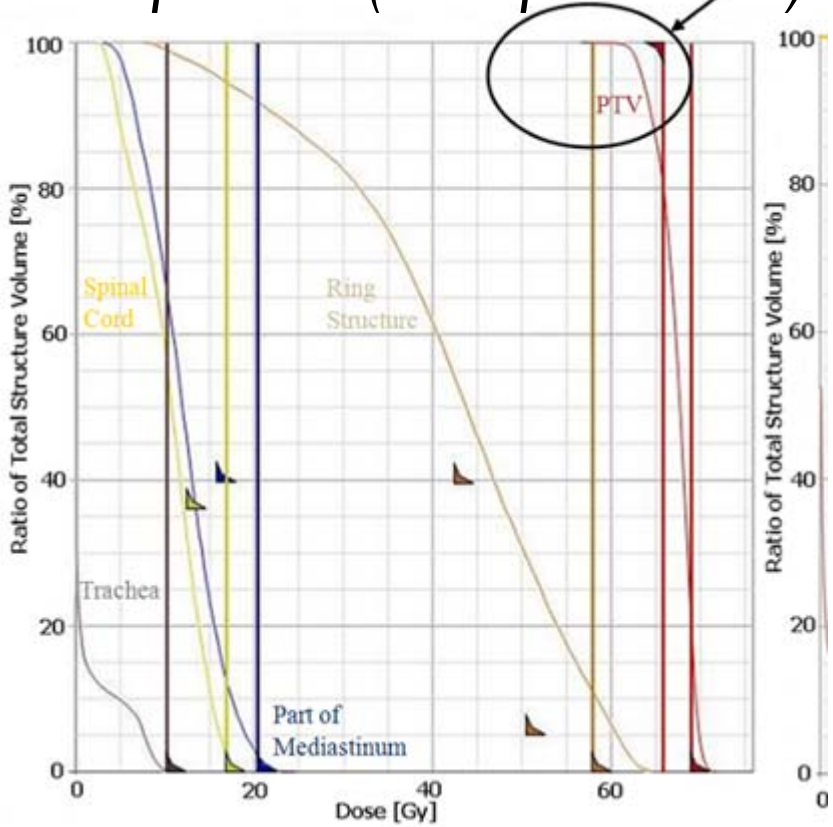


Verbakel ,W Proc. ASTRO 2009

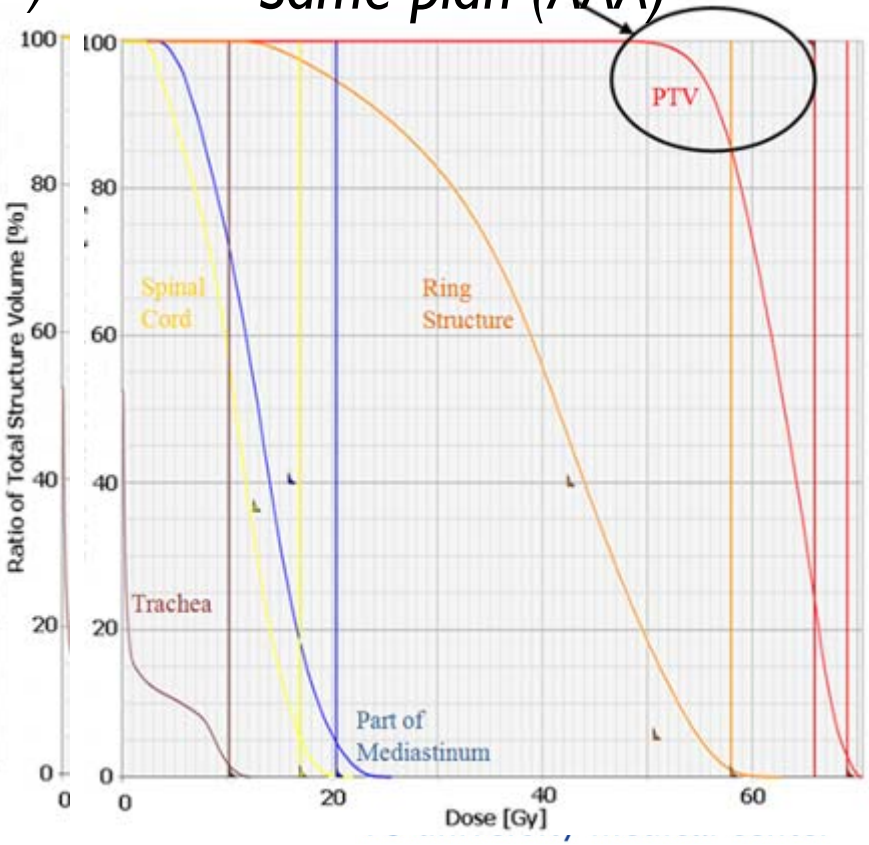
RapidArc for SBRT: Optimization

- Differences between dose calculation algorithms in optimization (Multi Resolution Dose Calculator) and AAA: PTV dose appears more homogeneous in the optimizer than in AAA.

DVH optimizer (end optimization)



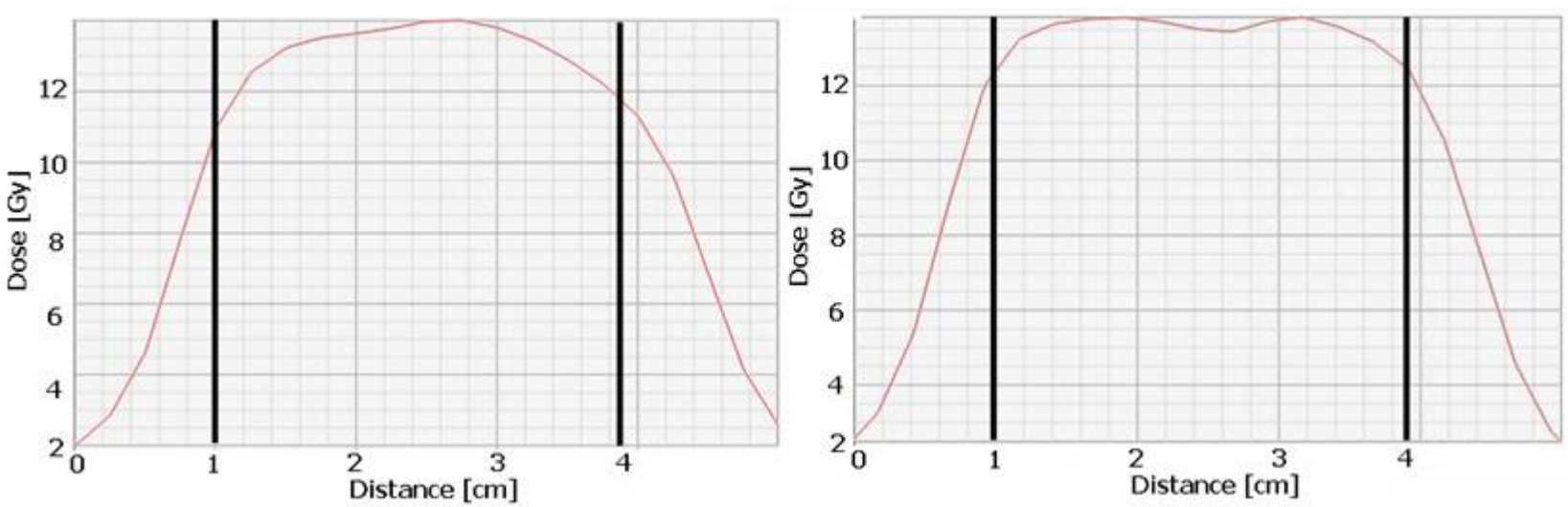
Same plan (AAA)



Sequential RA optimization - 2 arcs

- Typical plan > 2000 MU; extra imaging between arcs
- 2nd arc uses plan for first arc as 'Base Dose Plan'

1st arc (more inhomogeneous dose) 2nd arc



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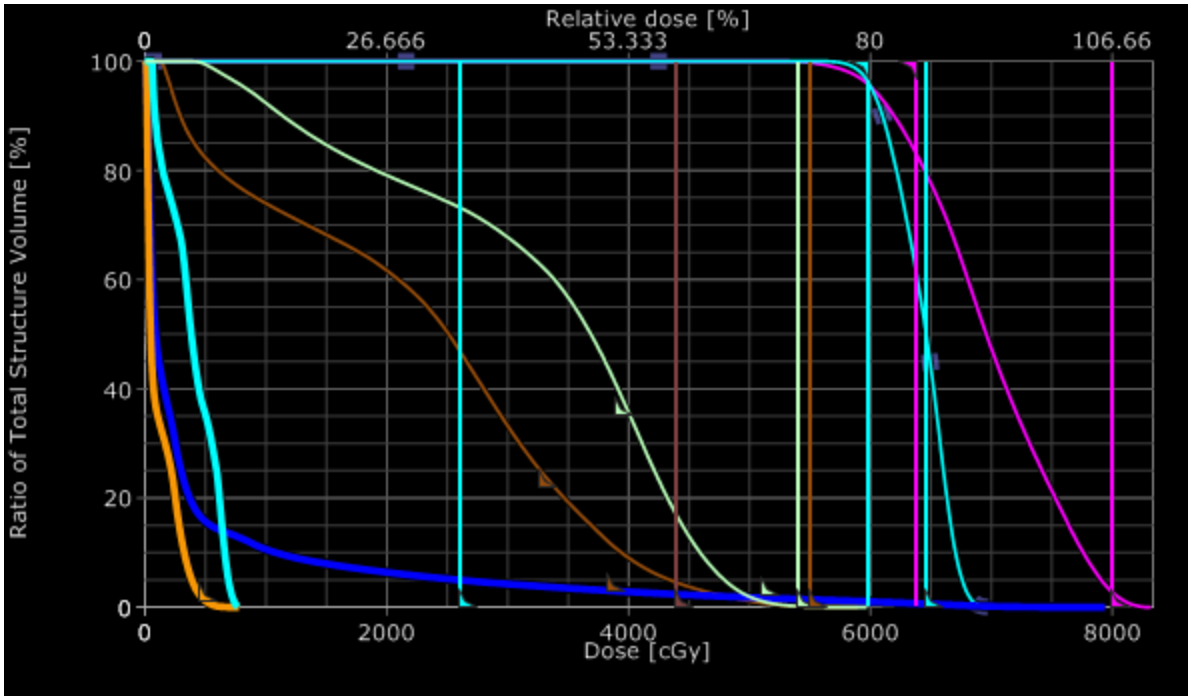
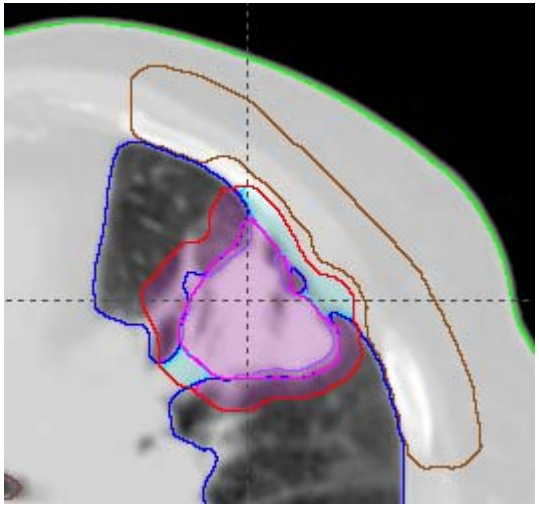
Typical optimization constraints

- PTV consisting of PTV_{OAR} + PTV_{lung}
- ≤140% of dose accepted in PTV_{lung} and ITV_{lung}
- Contralateral lung: low V5
- Ring for dose fall off (green line)
- Ribs doses >V40Gy minimized





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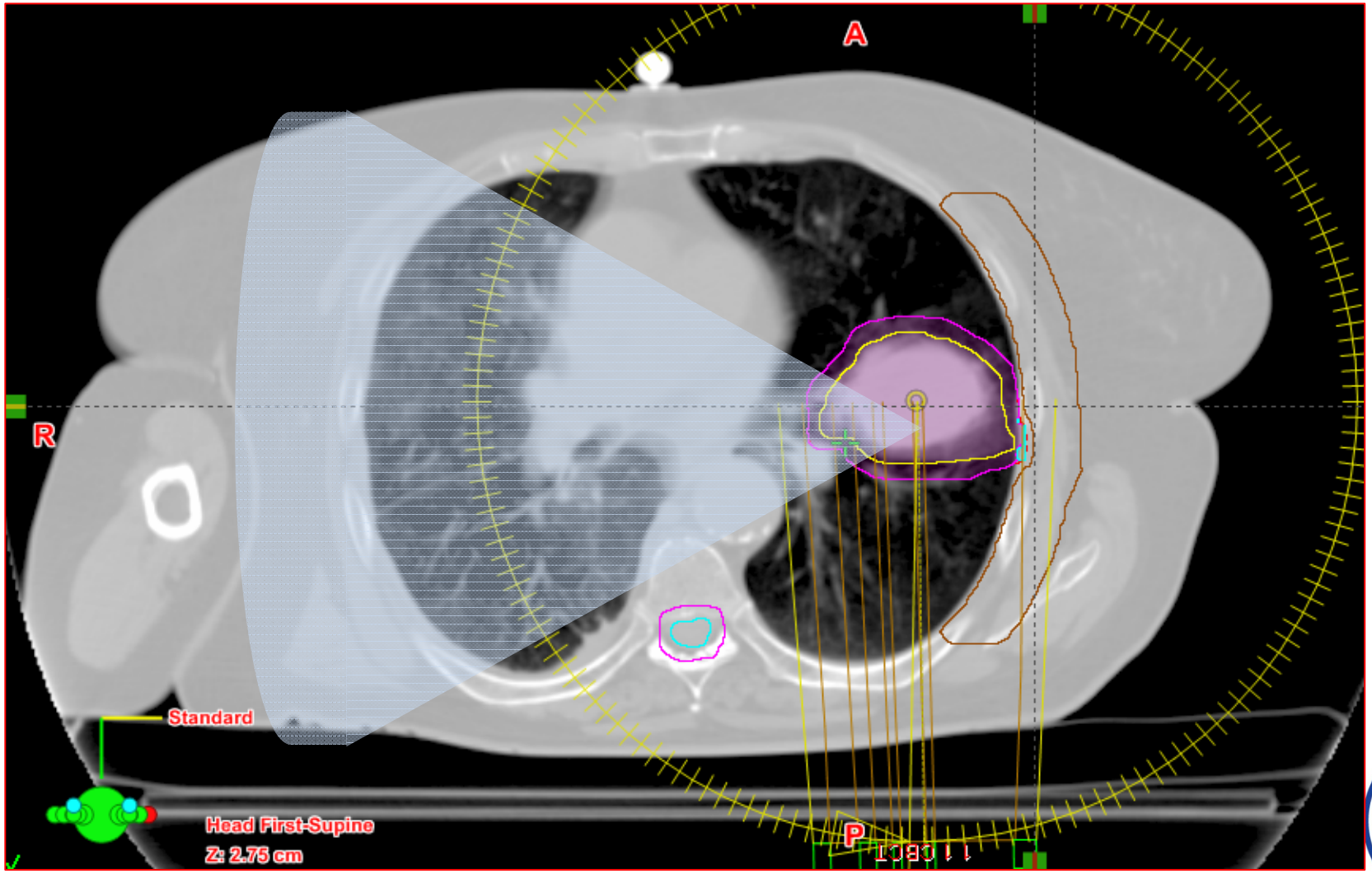
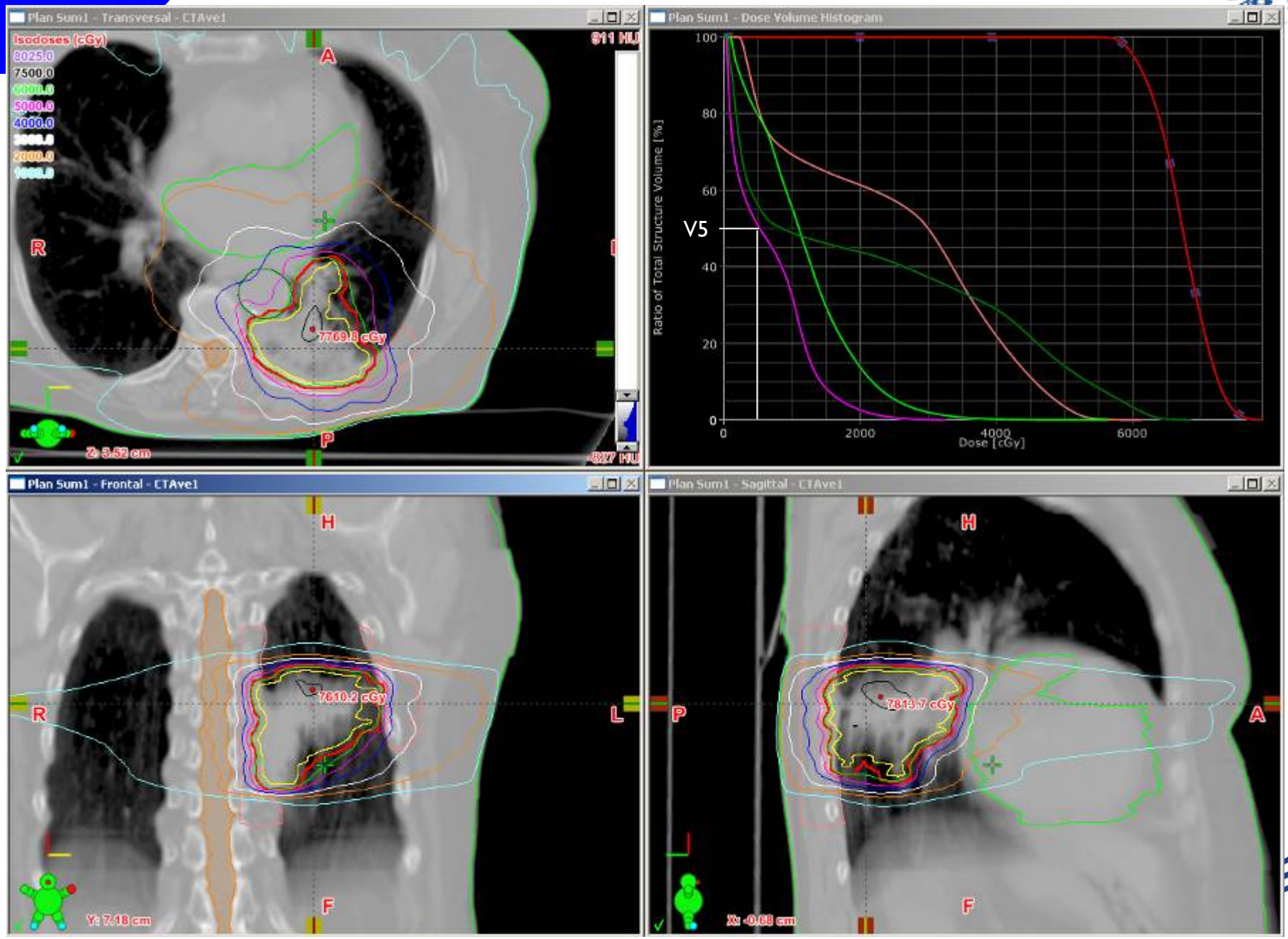
Limit contralateral lung V5 [*Ong C, ASTRO 2010*]

- Use of partial arcs or avoidance sector
- Our *preference* is for an *avoidance sector*



RapidArc applied in large tumors



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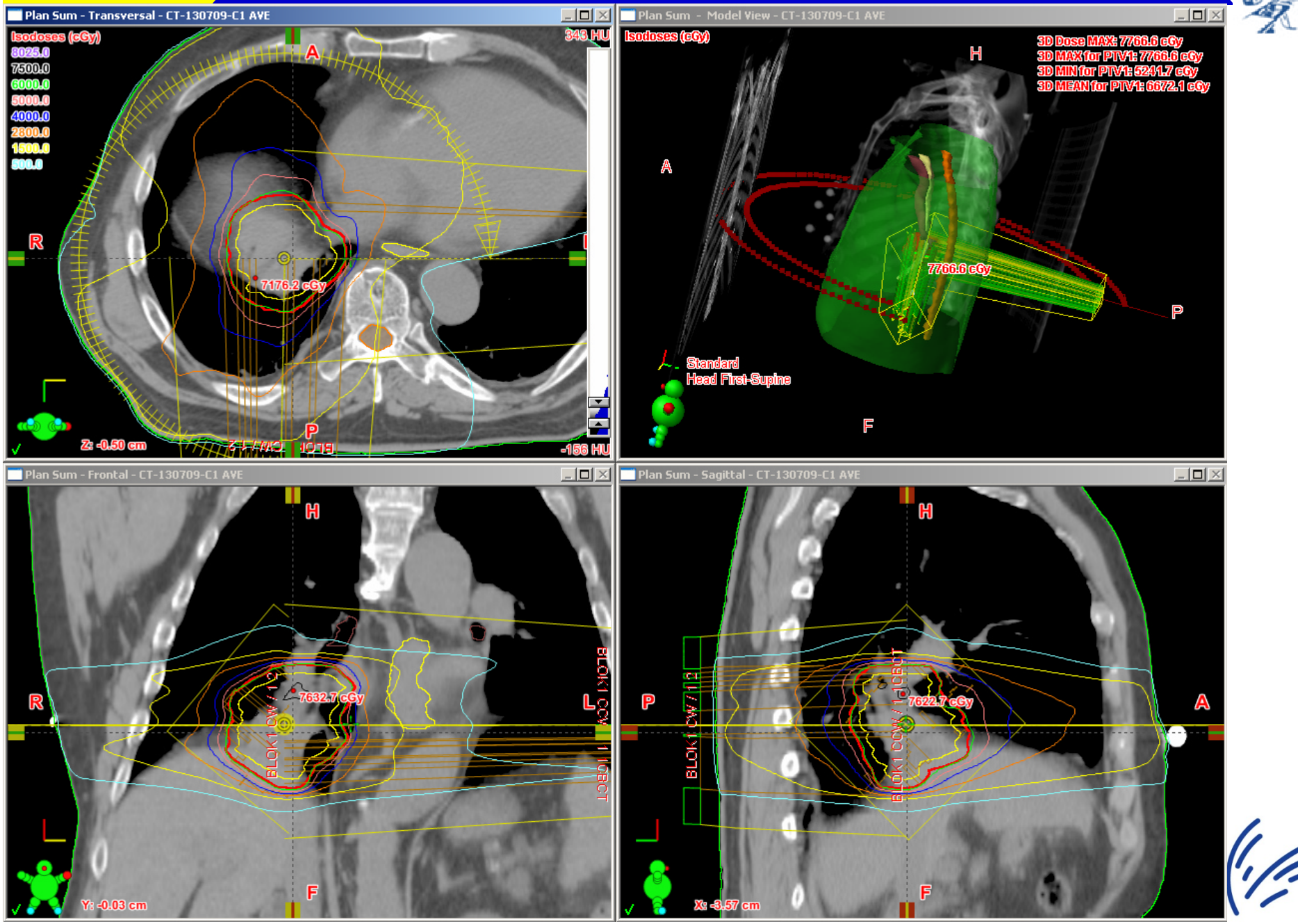
PTV > 200 cc: use of 2 partial arcs



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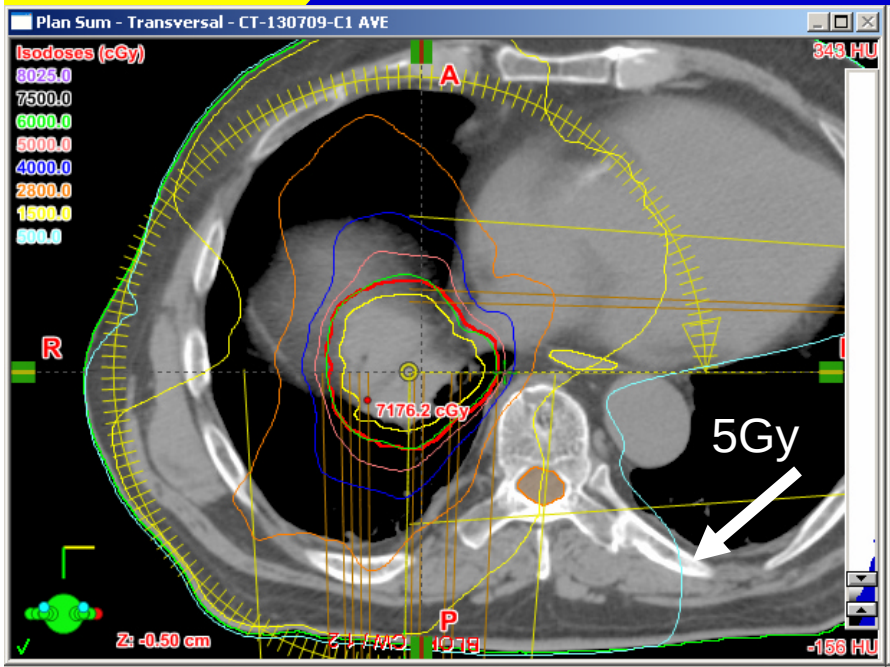
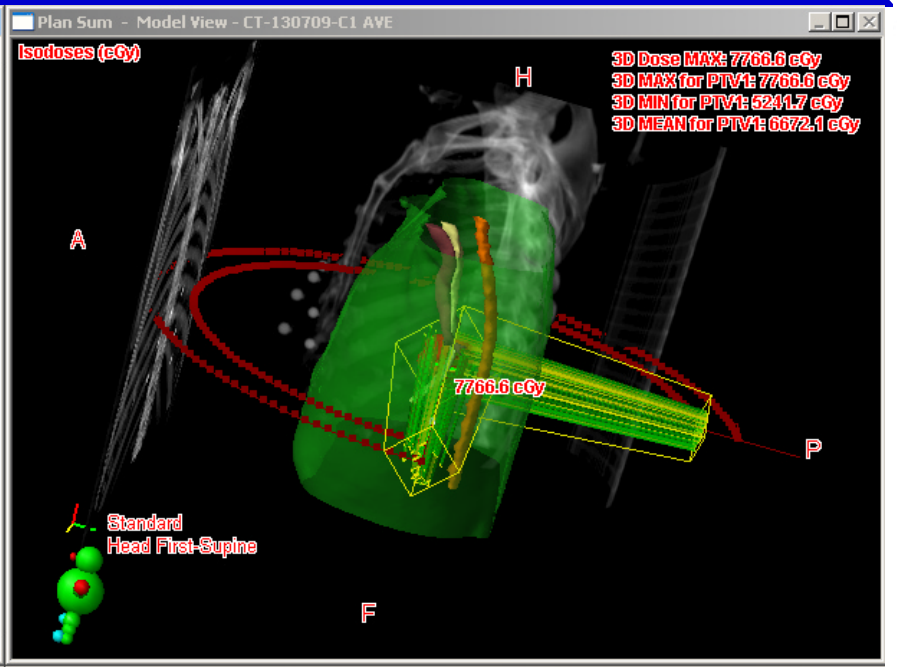
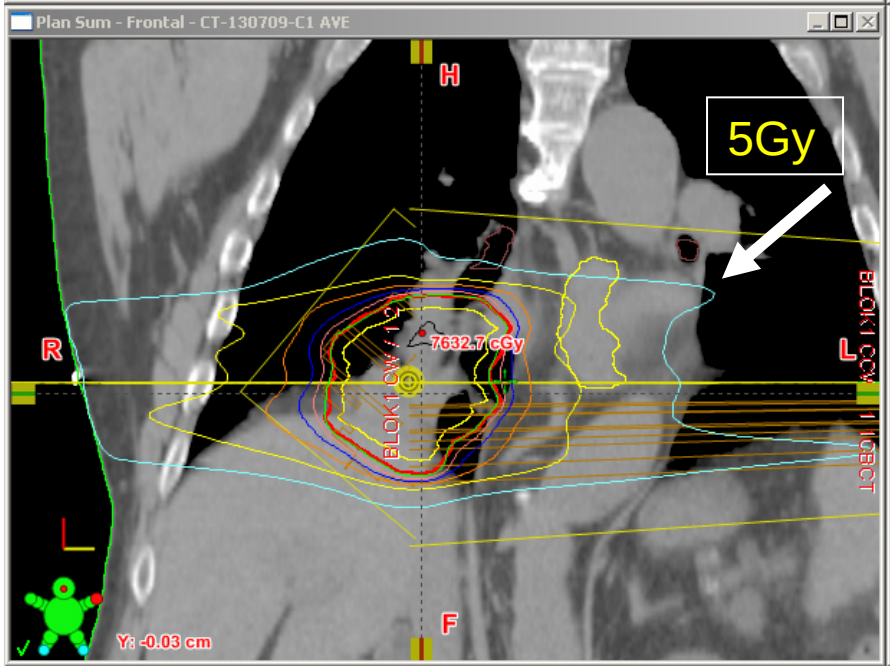
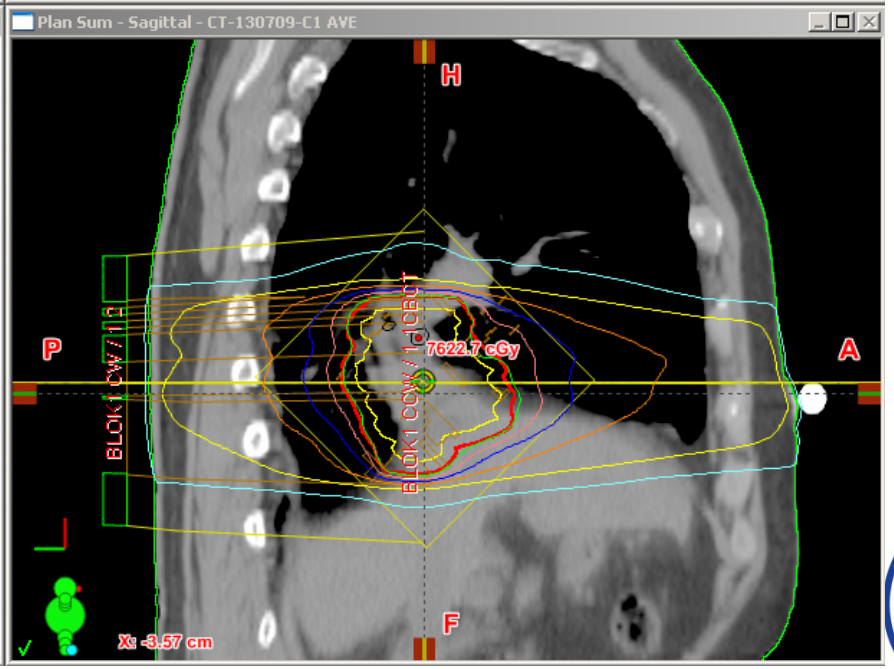
PTV > 200 cc: use of 2 partial arcs



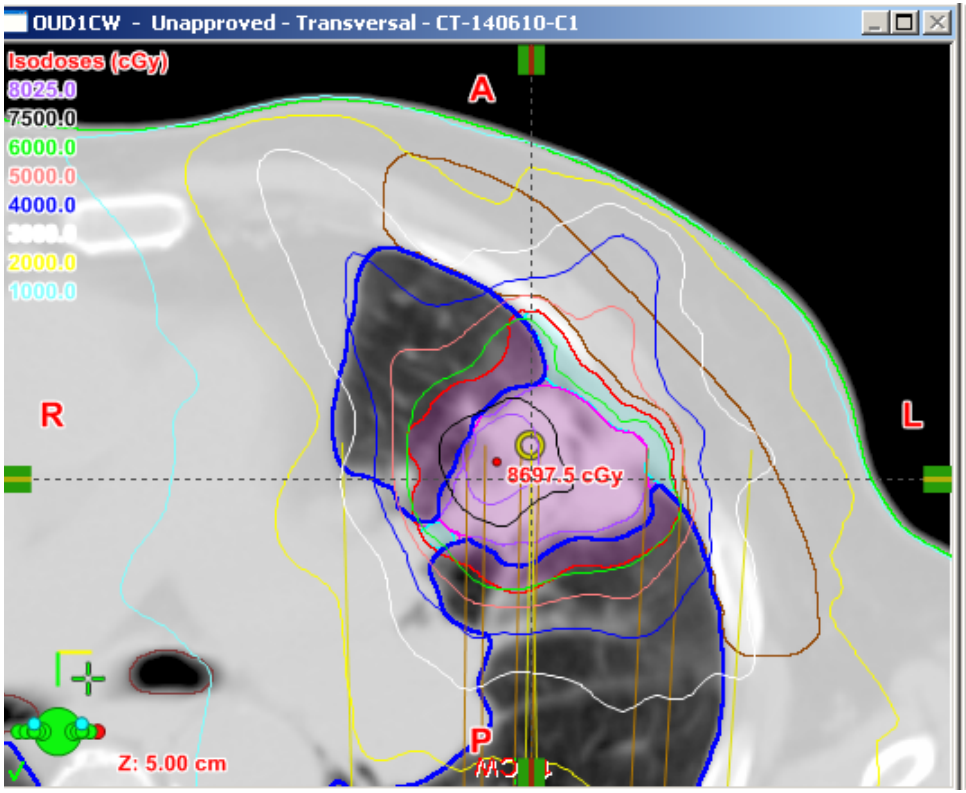


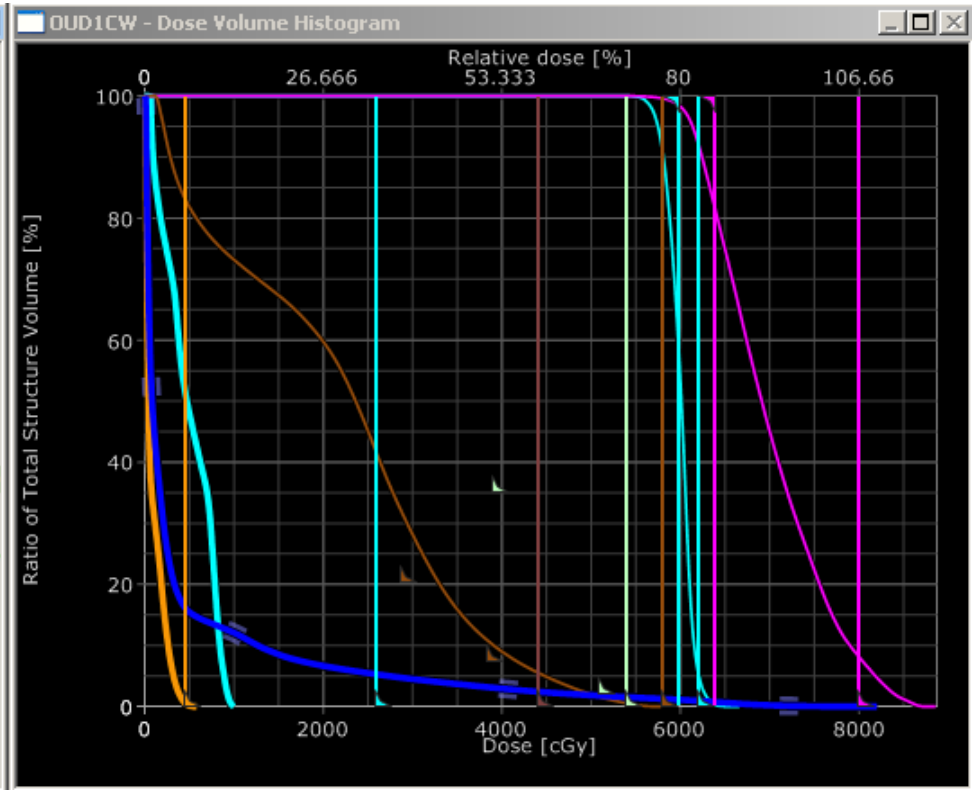




Example: Reducing chest wall dose

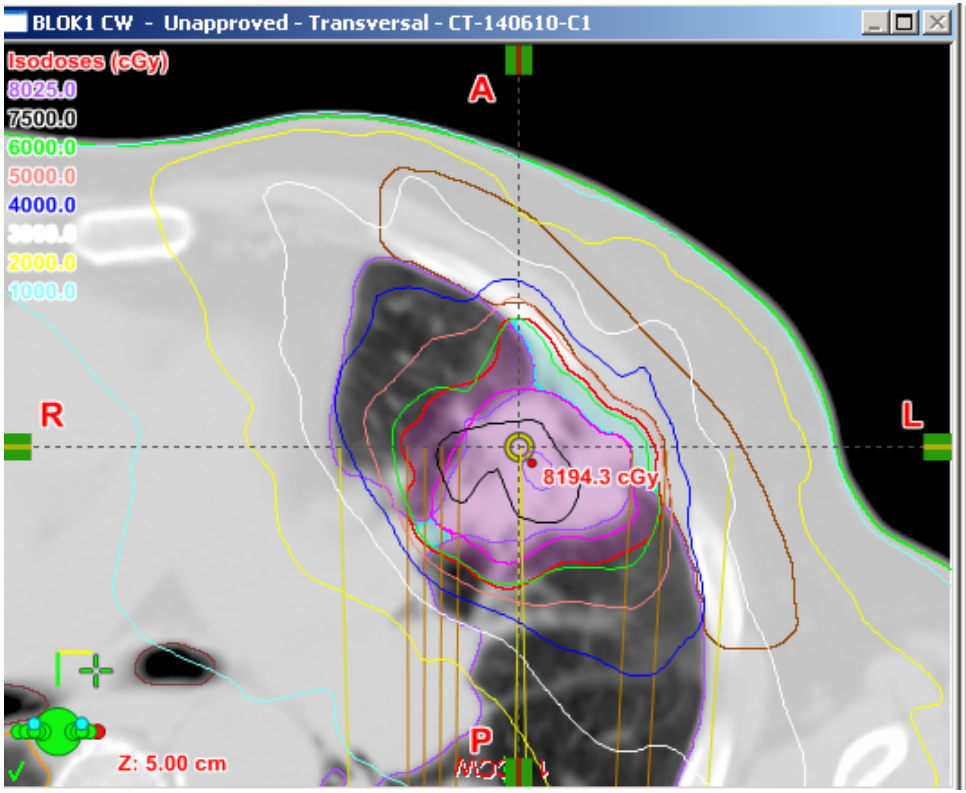
- Plan for 8x7.5 Gy
- Thorax dose: V40Gy and V60-65Gy (inside PTV)
- Initial plan: V40Gy=**9%**
- Narrow optimization window for PTV in OAR

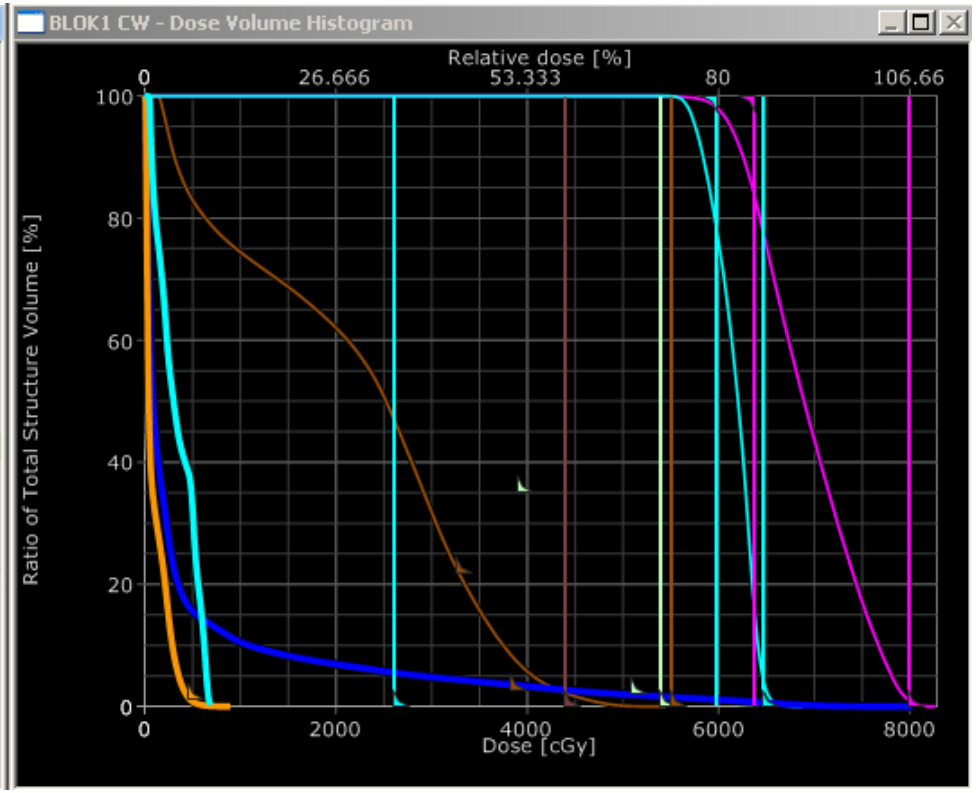




Example: Reducing chest wall dose

- New plan: V40Gy = **5.5%**
- Allows ≤64 Gy in PTV in OAR instead ≤62 Gy
- Allow slightly higher V5 in CL-lung

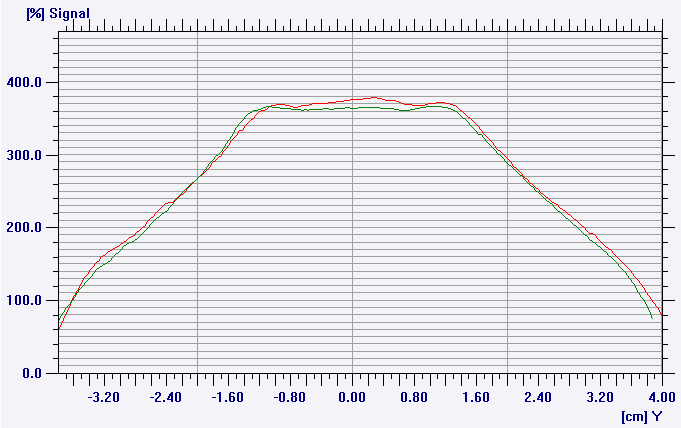




DOSIMETRIC IMPACT OF INTERPLAY EFFECT ON RAPIDARC LUNG STEREOTACTIC TREATMENT DELIVERY

CHINLOON ONG, WILKO F. A. R. VERBAKEL, PH.D., JOHAN P. CUIJPERS, PH.D., BEN J. SLOTMAN, M.D., PH.D., AND SURESH SENAN, M.R.C.P., F.R.C.R., PH.D.

- Background: Interplay between moving leaves and moving target can be important with Tomotherapy and conventional doses delivered using RapidArc
- Static measurements convoluted with motion, and compared with moving film
- Gamma (3%, 1 mm) > 1: 3-5%
- No interplay effects observed for RapidArc SBRT plans
  - *Measured in 11 patients with motion amplitude > 5 mm*
  - *For plans with excessive MU and 25 mm amplitude [Fig below]*



Lung SBRT using RapidArc: Clinical results

No reasons to indicate concerns about toxicity or efficacy

CLINICAL INVESTIGATION

RADIOLOGICAL AND CLINICAL PNEUMONITIS AFTER STEREOTACTIC LUNG RADIOTHERAPY: A MATCHED ANALYSIS OF THREE-DIMENSIONAL CONFORMAL AND VOLUMETRIC-MODULATED ARC THERAPY TECHNIQUES

David A. Palma, M.D., F.R.C.P.C.,* Suresh Senan, Ph.D., M.R.C.P., F.R.C.R.,* Cornelis J. A. Haasbeek, M.D., Ph.D.,* Wilko F. A. R. Verbakel, Ph.D.,* Andrew Vincent, Ph.D.,† and Frank Lagerwaard, M.D., Ph.D.*

Manuscript in press: Lung density changes after stereotactic radiotherapy: A quantitative analysis in 50 patients. DA Palma, et al

Manuscript under review: Treatment of large stage I-II lung tumors using SBRT: planning considerations and early toxicity. Ong CL, et al

Conclusions

- Fast lung SBRT in <6.5 mins delivery time
  - Total linac time (+ CBCT set-up) 20 minutes
  - Superior OAR sparing possible
  - Less chance for intrafraction motion
- No interplay effect between moving tumor and moving leaves
- More time for appropriate and efficient IGRT

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Thank you for your attention

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