Helical SBRT for Cranial Spinal Treatments

James W. Anderson

Wednesday, May 06, 2015

RUSH UNIVERSITY MEDICAL CENTER

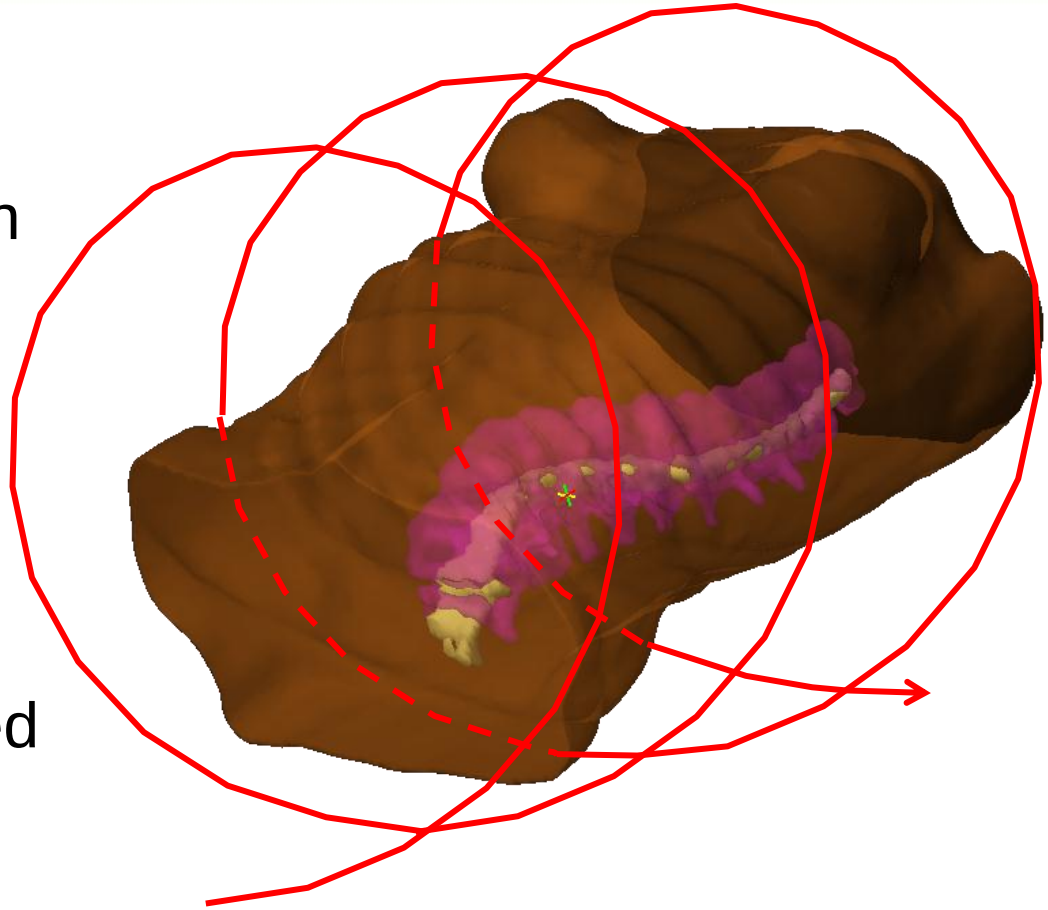
IT'S HOW MEDICINE SHOULD BE

Dynamic Couch Motion

- Many vendors are beginning to allow couch motion during radiation delivery.
- Varian “developer mode” allows institutions to perform research using these types of treatments.
- Tomotherapy uses one directional dynamic couch motion to produce helical treatments.
- Can the same thing be done with a conventional linac?

Helical Delivery

- Goals:
  - Treat long targets with a single setup by moving the couch longitudinally during gantry rotation.
  - Plan rapid-arc helical delivery using modified VMAT optimization.



  - Produce plans comparable to those achievable with Tomotherapy.
  - Measure a treatment with arccheck as a proof of concept

Challenges

A. Developer mode is expensive and has a significant learning curve.

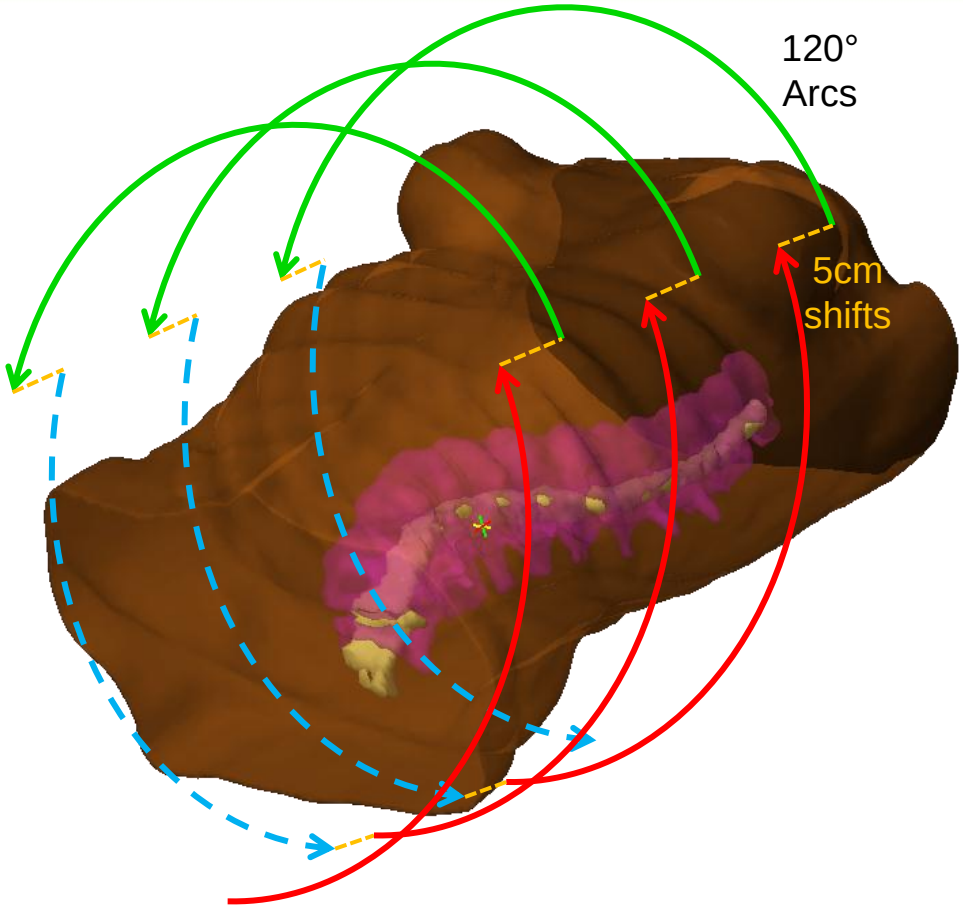
B. Eclipse VMAT optimization does not allow dynamic couch motion.

C. Modern linac gantries do not allow continual rotation, i.e. can’t pass 185°E.

D. Arccheck can not measure treatment fields longer than 20cm.

Modeling Helical Delivery

- VMAT optimization with Eclipse works even if the arcs have different isocenters.
- Helical delivery was modeled by splitting the helical revolution into a series of transverse arcs

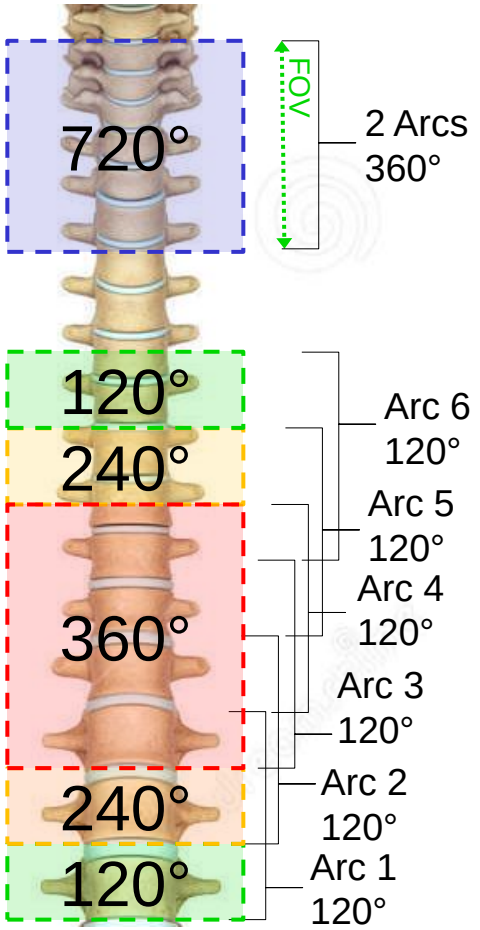


- The dynamic couch can then be modeled by a longitudinal shift between the isocenter of each arc.
- Eclipse *does* have a limit of 10 arcs per treatment plan.

Minimum Modulation per Slice

- Typical spine SBRT treatments use two full arcs, so each transverse slice gets 720° of modulation.
- Both true helical delivery and the arc-shift approximation mean each transverse slice receives less modulation.
- Amount of modulation depends heavily on helical pitch
- How much modulation is sufficient?

Typical spine SBRT

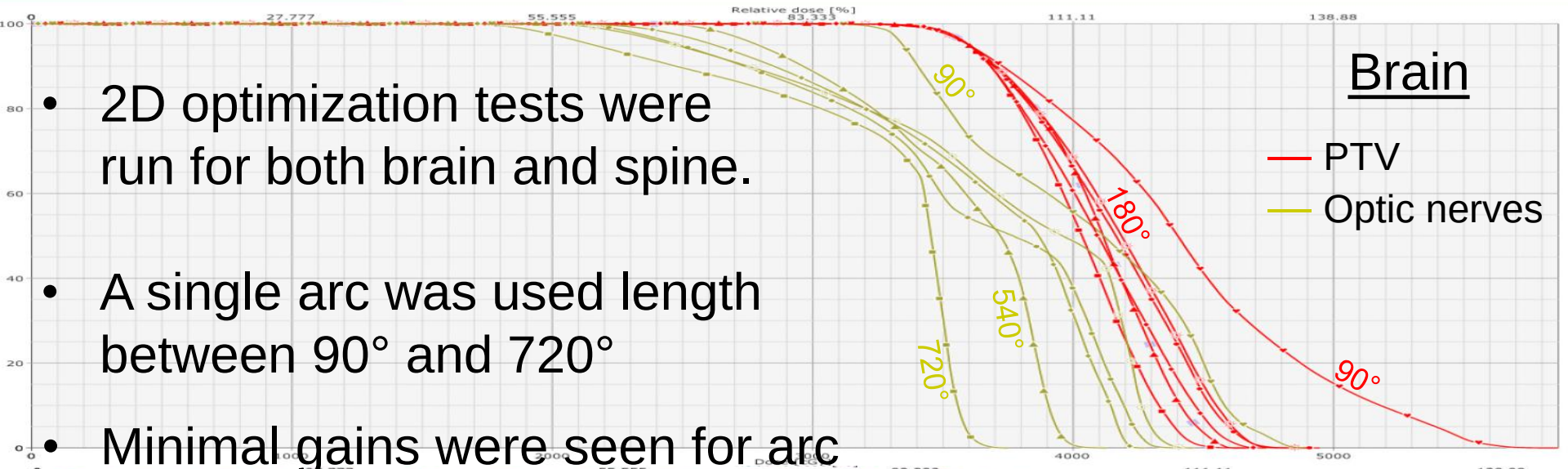


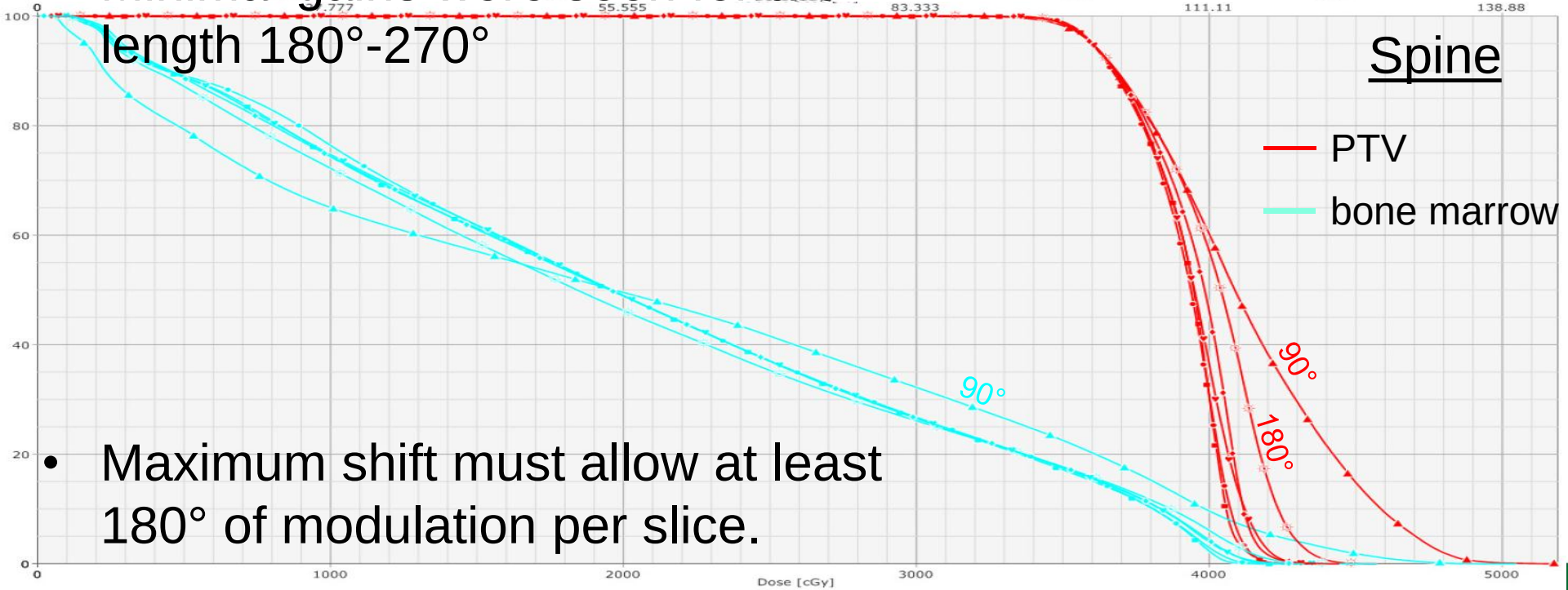
Arc-shift approximation

RUSH UNIVERSITY MEDICAL CENTER

Minimum Modulation per Slice

- 2D optimization tests were run for both brain and spine.
- A single arc was used length between 90° and 720°
- Minimal gains were seen for arc length 180°-270°
- Maximum shift must allow at least 180° of modulation per slice.

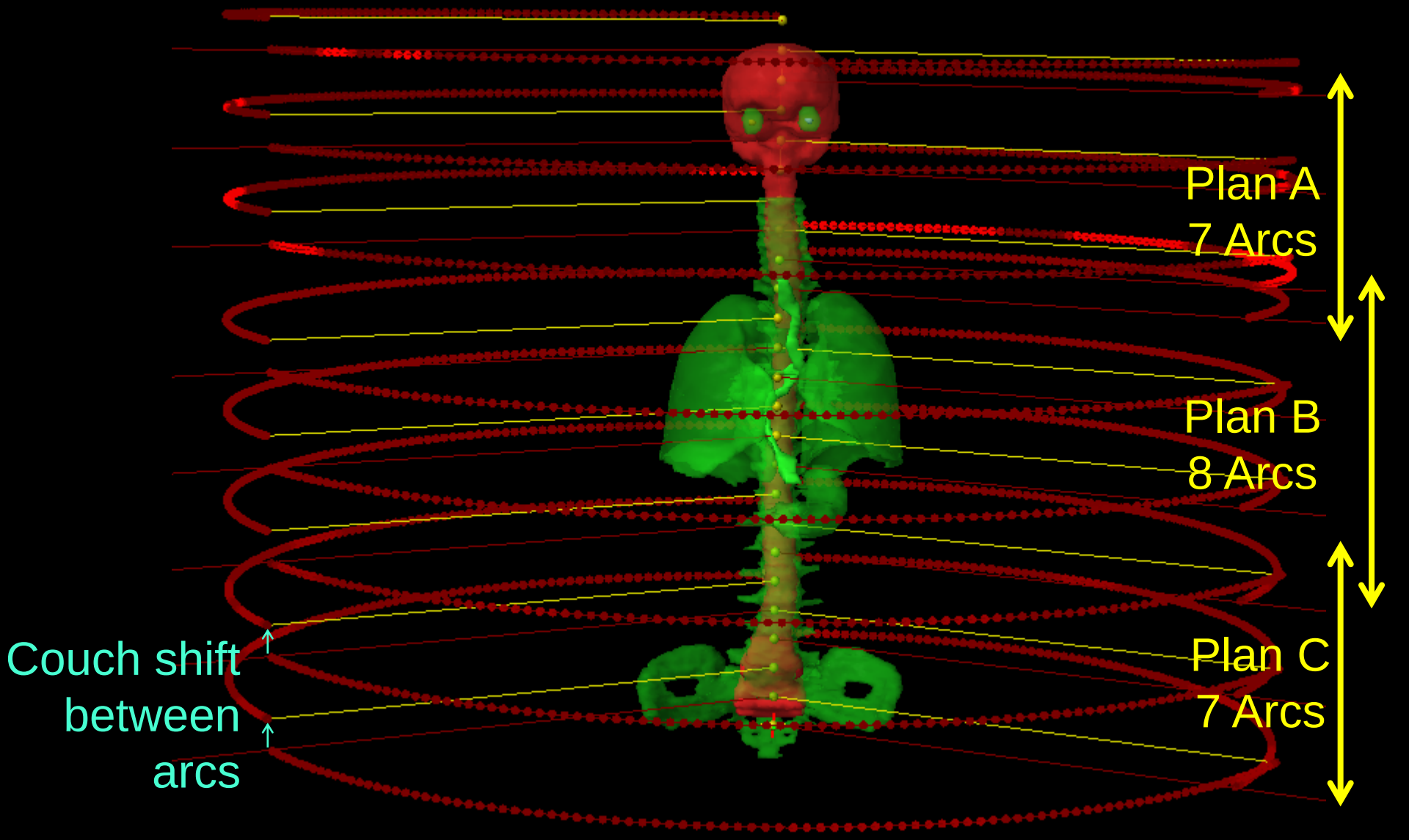




Planning Tests

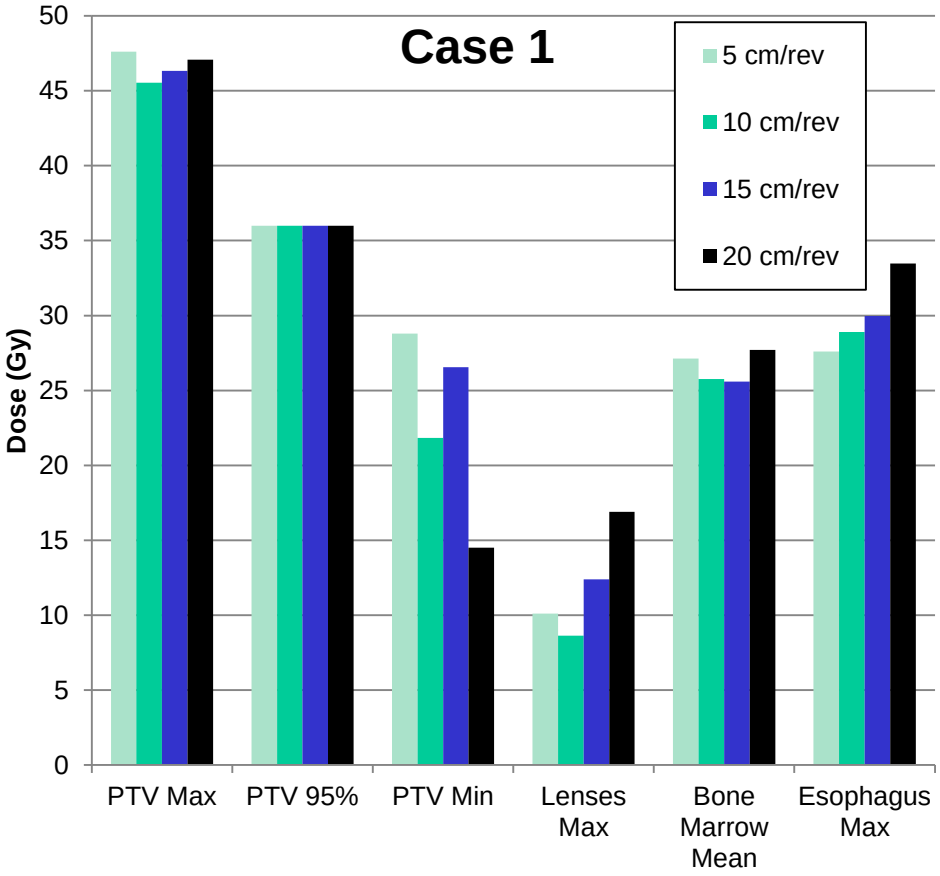
- Arc-shift approximation planning was done on data from 5 CSI patients.
- Arc length was 120°
- Shift was varied between 5, 10, 15, and 20cm. (20cm has ~360° of modulation per slice)
- PTV height varied from 71 to 77cm; this meant more than 10 arcs were needed for all plans.
- Plans were optimized in 10 arc “portions”, with later portions being optimized on the partial dose.

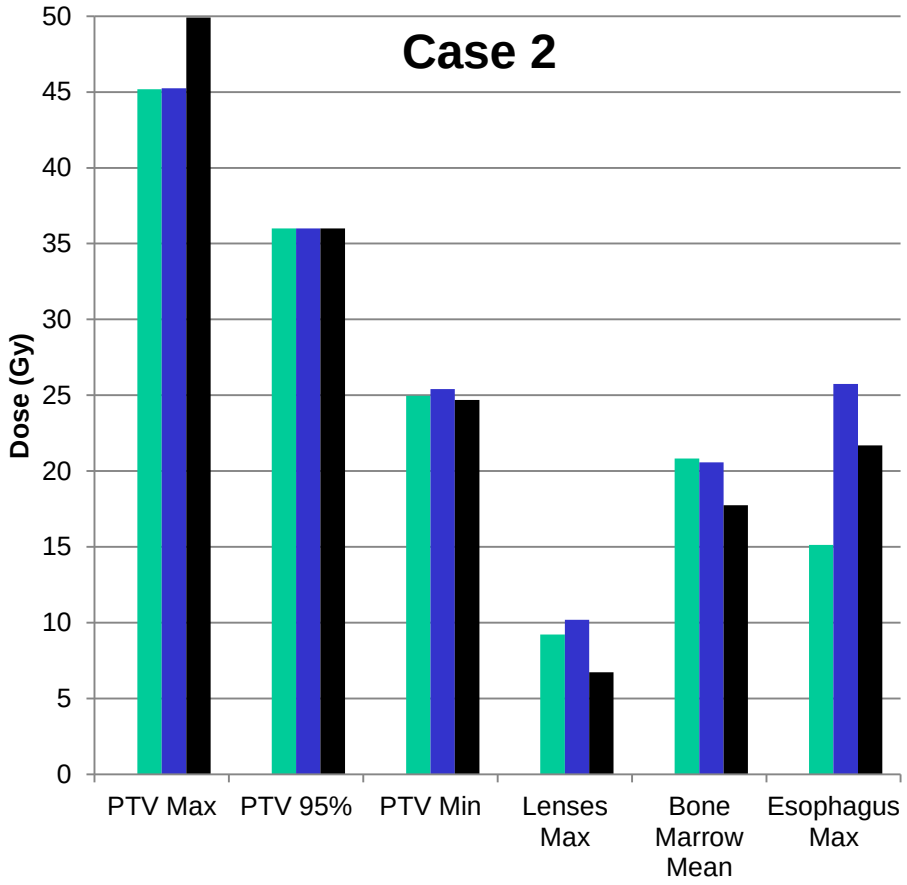
Modeling Helical Trajectory



Individual Case Results

- Results from two cases comparing effect of shift.



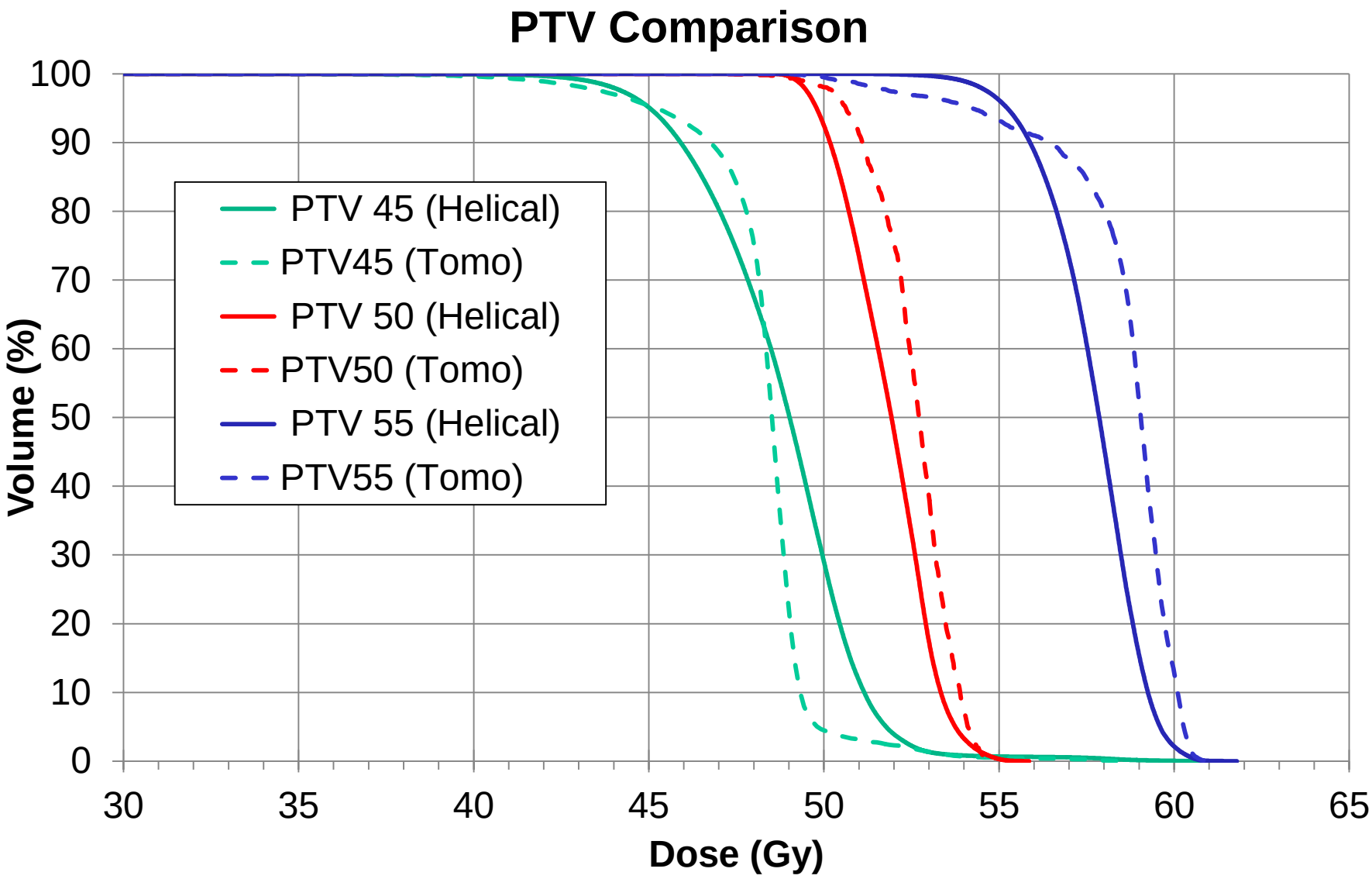


- Shift has little effect on dosimetric results.

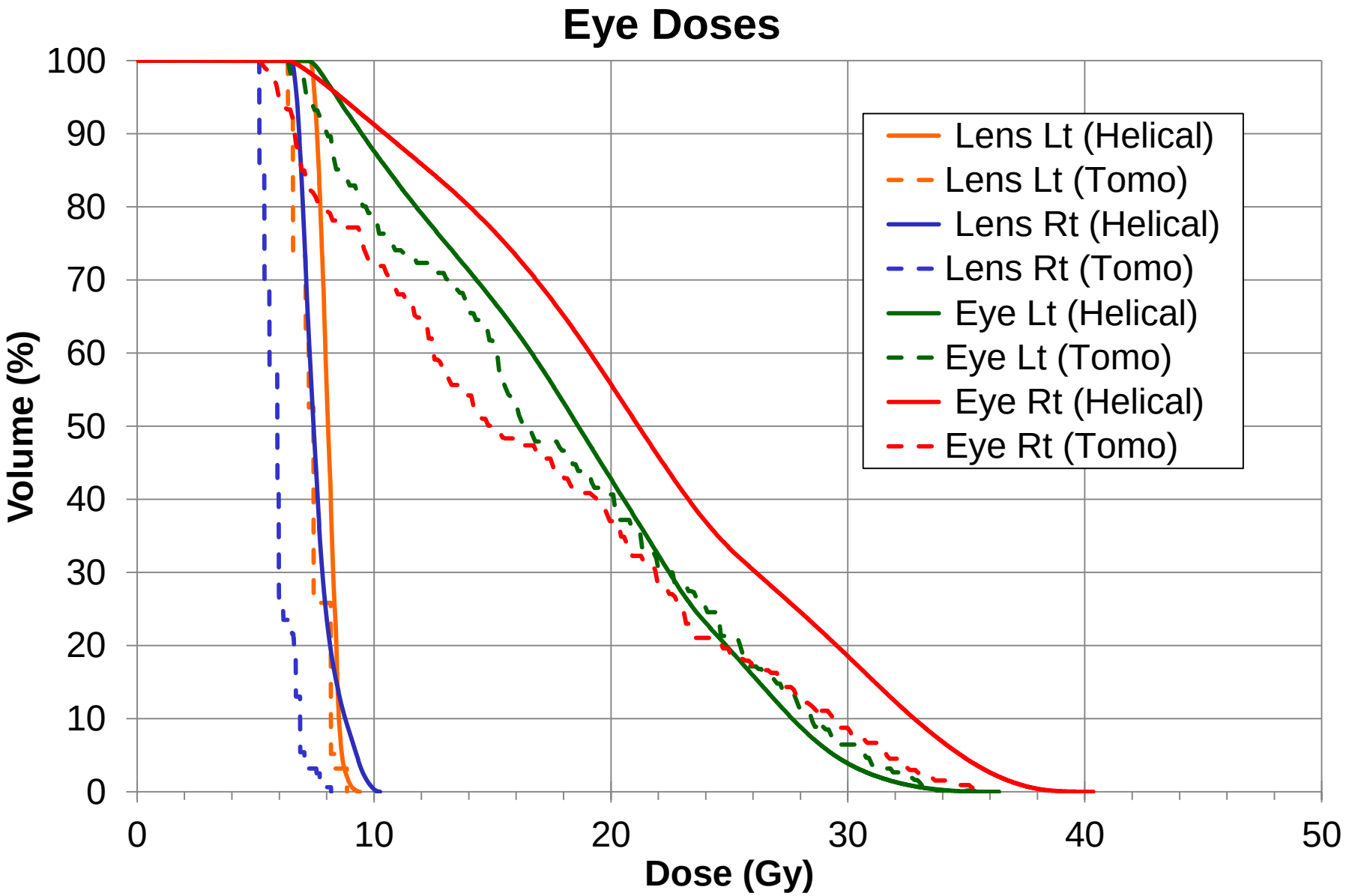
Helical SBRT and Tomotherapy

- Tomotherapy Comparsion
  - One case was optimized using the same criteria as a clinical tomotherapy treatment.
  - The clinical prescription involved three dose targets of 45, 50, and 55 Gy, as well as OAR restrictions to critical structures.
  - A shift of 20cm was used for the helical arc-shift plan.

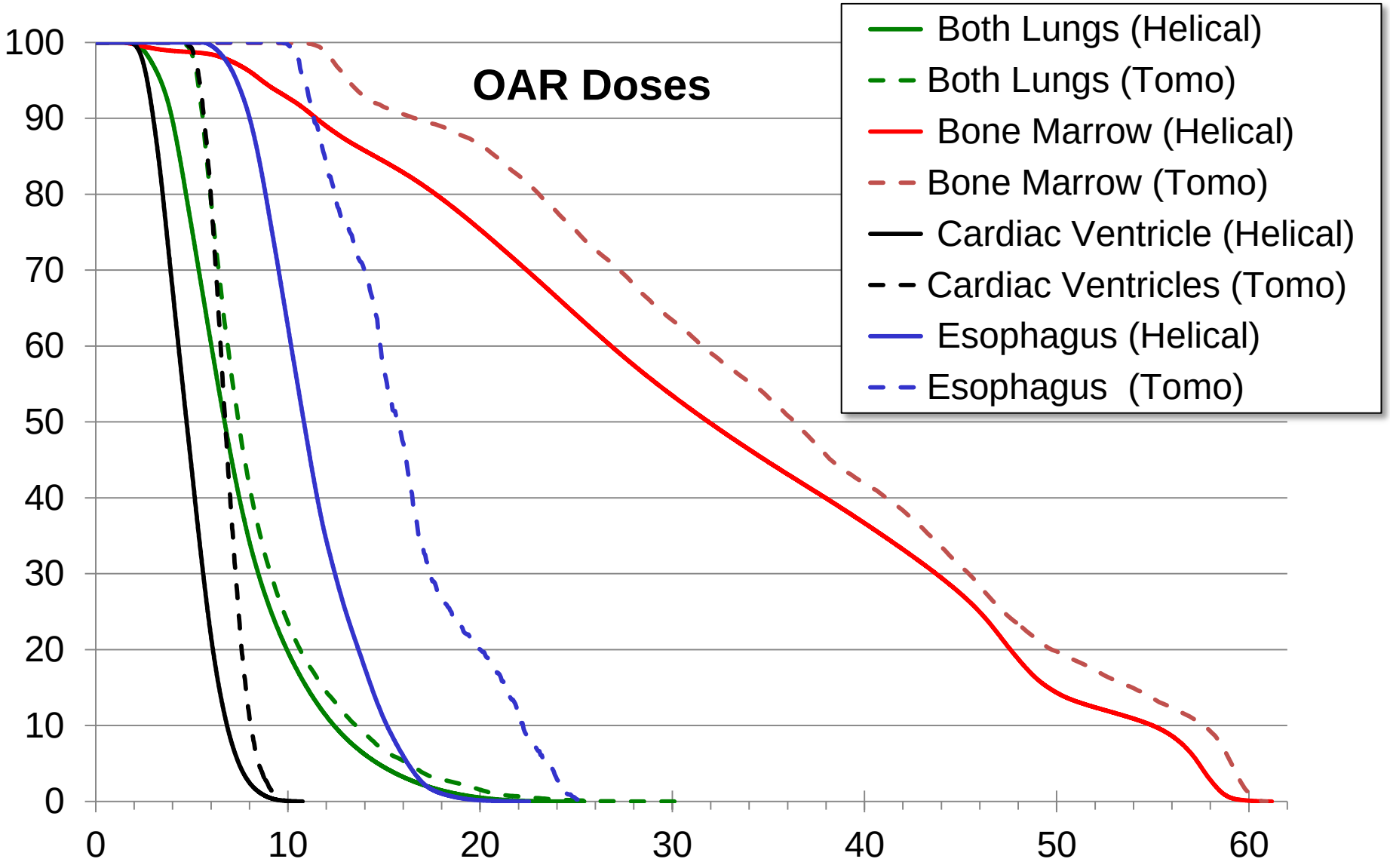
Helical SBRT and Tomotherapy



Helical SBRT and Tomotherapy



Helical SBRT and Tomotherapy

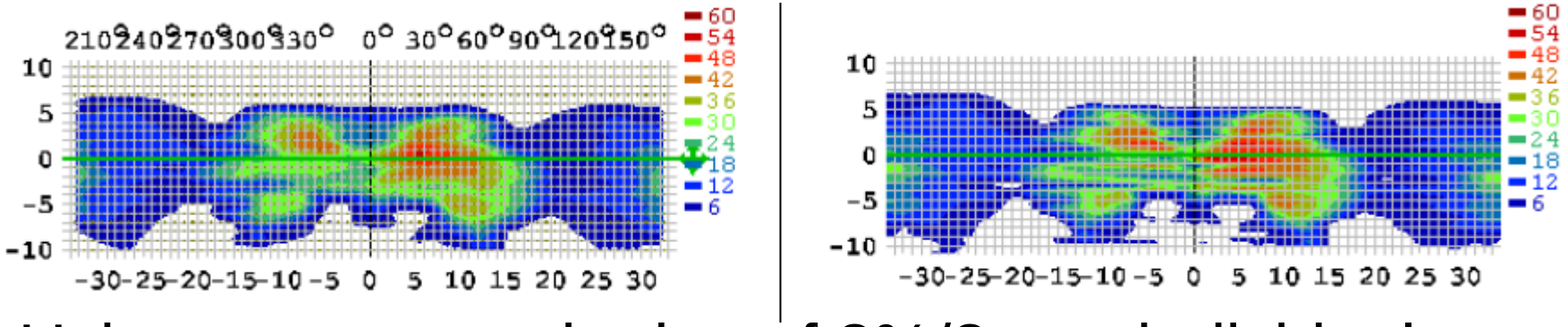


Deviations from True Helical

- MLC positions at the end of one 120° arc do not impose any limitations on leaf positions at the start of the next arc.
- Arcs in which the gantry passes 180° are currently invalid, though slip-ring technology may be in the next generation of linacs.
- Optimization using multiple plans can produce boundary effects.

Proof of Concept

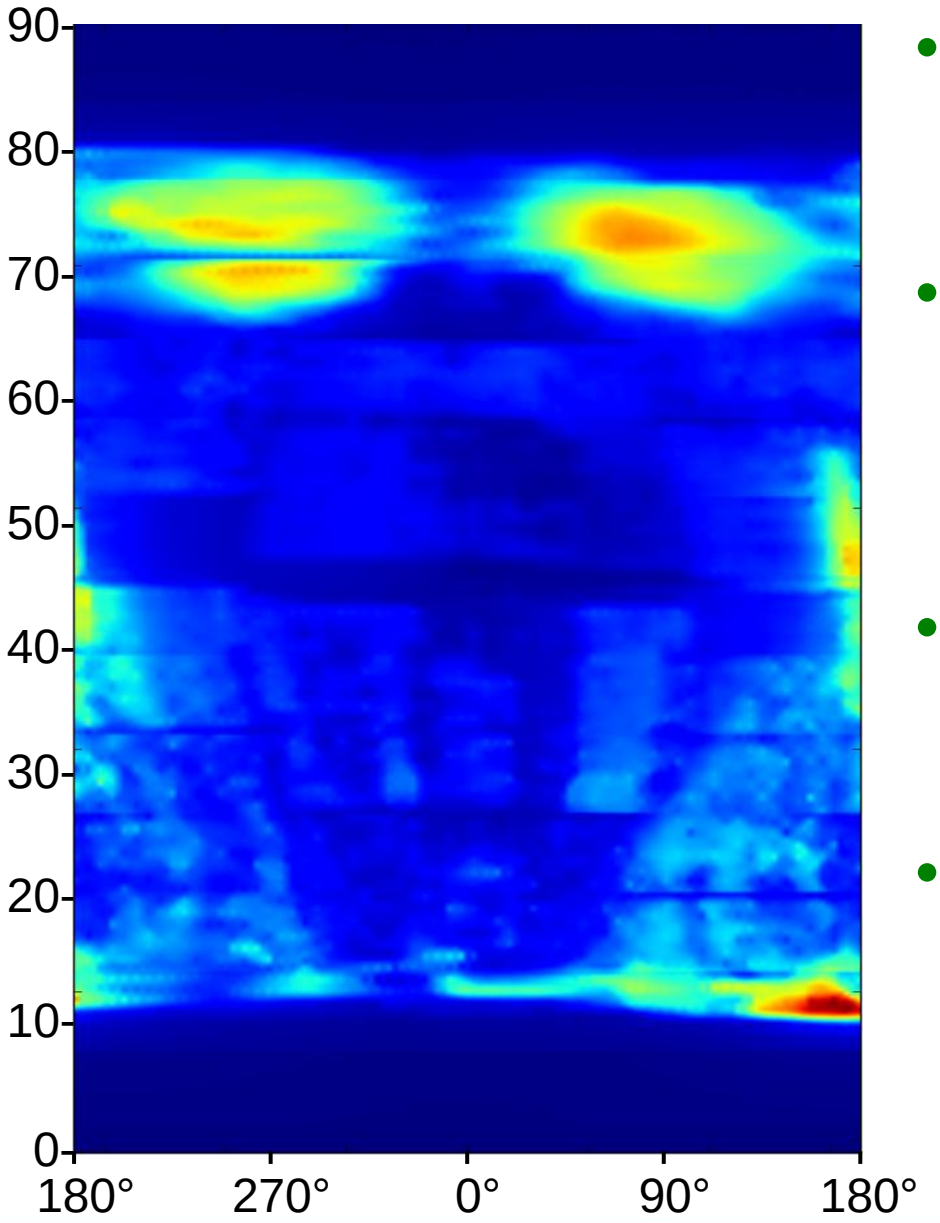
- One plan was delivered to arccheck as a proof of concept.
- Each of the 12 arcs were delivered with arccheck at isocenter and no couch shifts.



- Using a gamma criterion of 3%/2mm, individual arcs passed with an average rate of 98%.
- Data was extracted, shifted and summed to produce a full treatment measurement.

RUSH UNIVERSITY MEDICAL CENTER

Proof of Concept



- Sum of individual 120° arcs.
- Brain region is clearly evident, as are portions of spine.
- Inferior hot spot due to end effect.
- Transverse discontinuities are due to lack of MLC matching and optimizing across multiple plans.

Summary

- Helical CSI treatment using a conventional linac was modelled using available technology.
- Optimized plans were found to have comparable results to Tomotherapy treatments.
- One modelled plan was delivered and measurements combined as proof of concept.