The Impact of Arc Geometry on Lung SBRT Plan Quality

Tyrone Hamilton, MBA, R.T. T, Jiahan Zhang, PhD, Jon Wolf, CMD, Tosin Kayode, CMD, Kristin A. Higgins, MD, Jeffrey Bradley, MD, Xiaofeng Yang, PhD, Eduard Schreibmann, PhD, Justin Roper, PhD

Department of Radiation Oncology, Winship Cancer Institute of Emory University, Atlanta, GA

INTRODUCTION

Purpose: This study investigates the impact of arc geometry on lung SBRT plan quality.

- Lung cancer is the most common cause of cancer death in the US.
- Several clinical trials have demonstrated the efficacy and safety of SBRT for patients with early-stage lung cancer. While SBRT offers advantageous local control, SBRT may not be an option for patients with bulky localized tumors because of excessive dose to the nearby healthy tissues.
- Now that the clearance zone can be mapped in the treatment planning system, it may be possible to configure beams in dosimetrically advantageous arrangements that better spare healthy tissues, thereby reducing the risk of toxicity and making SBRT an option for a greater number of lung cancer patients.

METHODS

- Twelve challenging clinical cases were identified with chest wall V30Gy > 30 cc, which was attributable to bulky disease.
- The clearance zone was mapped using Radformation software.
- Cases were replanned at 50 Gy in 5 fractions using 4 different VMAT geometries: coplanar lateral, coplanar oblique, non-coplanar lateral and non-coplanar oblique arcs.
- Couch angles were typically ± 15° on non-coplanar plans. Lateral arcs spanned 180° on the affected side whereas the 180° oblique arcs crossed midline to minimize the path length to the target and to avoid critical OARs.
- The same three optimization objectives were applied across all plans to achieve PTV coverage, steepen the dose gradient via the normal tissue objective and reduce monitor units (MUs).
- When needed, max dose objectives were added for the esophagus, great vessels, heart, spinal cord and/or trachea.
- Plans were normalized to achieve 95% PTV coverage, then evaluated for dose conformity, OAR dosimetric endpoints and MUs. Clinical plans were used to benchmark the results.

RESULTS

- In general, non-coplanar arcs had the greatest impact on making the dose distribution more compact. Smaller gains were achieved by using oblique arcs..
- CI50%: clinical 3.92±0.69, cpLAT 3.35±0.28, cpOBL 3.33±0.30, ncpLAT 2.98±0.23 and ncpOBL 2.95±0.23.
- Lung V20Gy[%]: clinical 6.1±4.3, cpLAT 5.7±4.1, cpOBL 5.3±3.8, ncpLAT 5.2±3.9 and ncpOBL 5.0±3.8.
- While all clinical plans had chest wall V30Gy > 30 cc, the non-coplanar arc configurations reduced V30Gy to under 30 cc in half of the cases.
- For left-sided tumors, oblique arcs under the couch better spared the heart: V10Gy[%] clinical 6.6±11.8, cpLAT 7.4±13.8, cpOBL 3.4±6.1, ncpLAT 6.8±13.6 and ncpOBL 3.2±6.0.

RESULTS

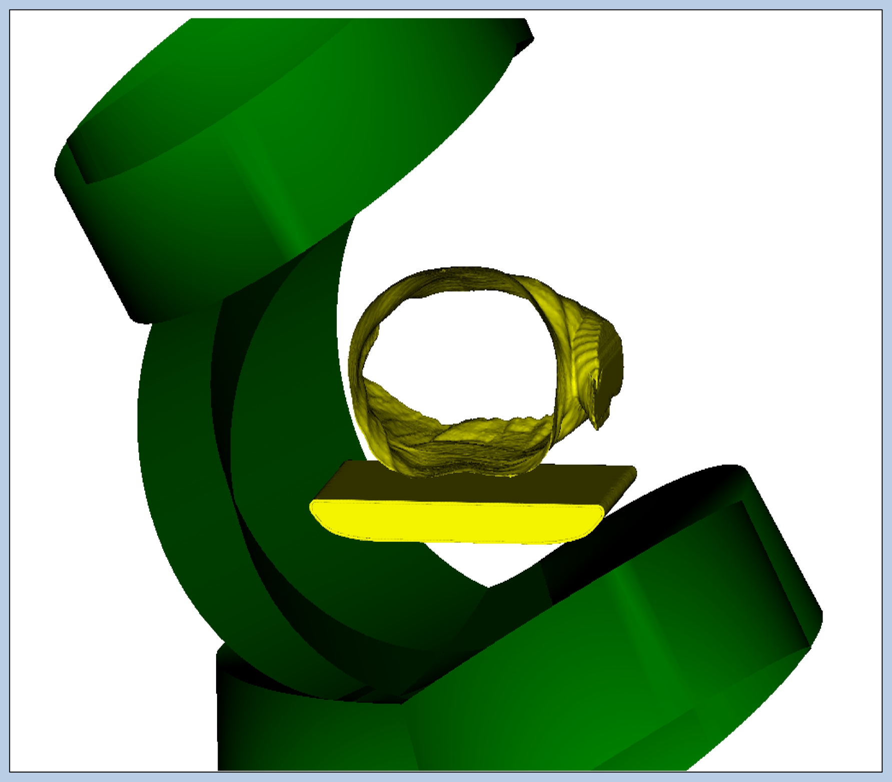

Fig 1. The gantry (green) safely avoids the patient and couch (yellow).

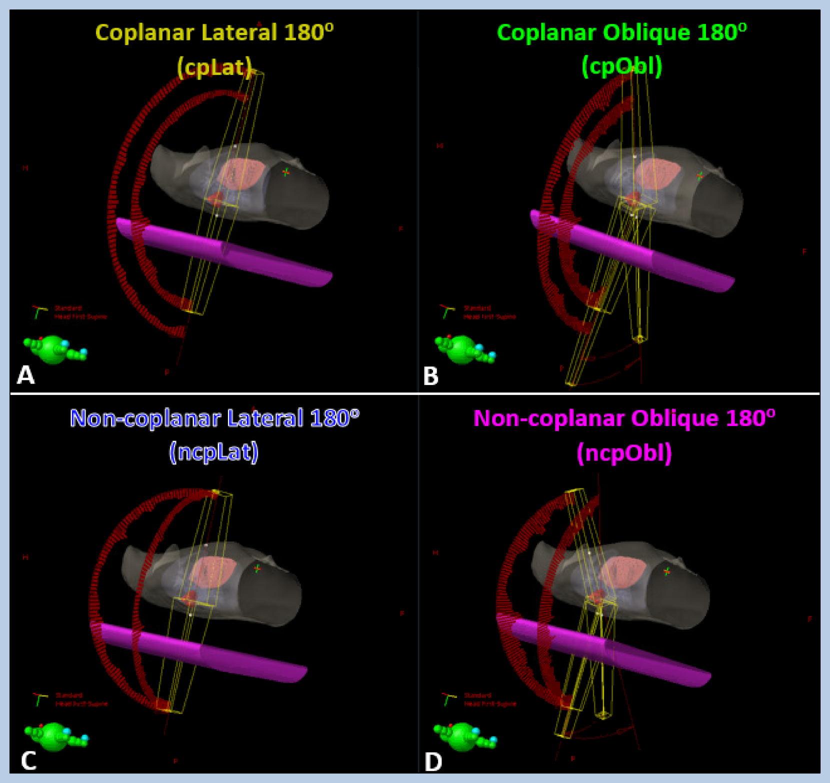

Fig 2. VMAT arc geometries: A) cpLat, B) cpObl, C) ncpLat and D) ncpObl.

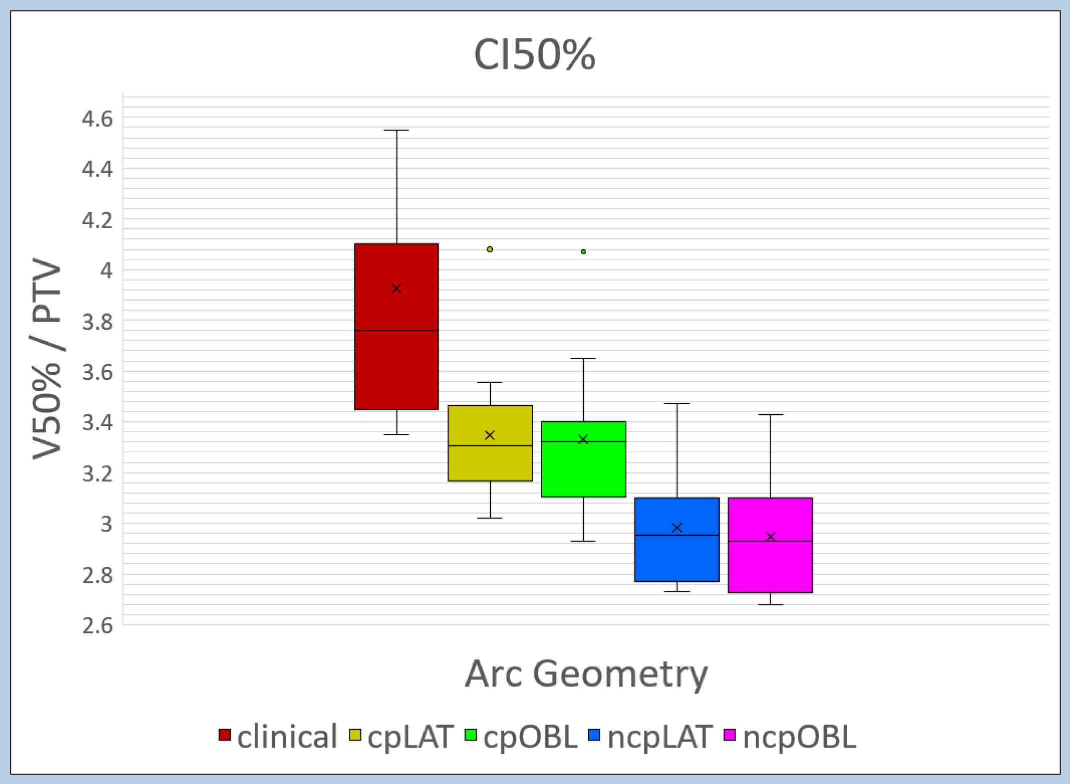

Fig 3. Volume of tissues receiving ≥50% Rx dose. Non-coplanar arcs reduce the CI50%.

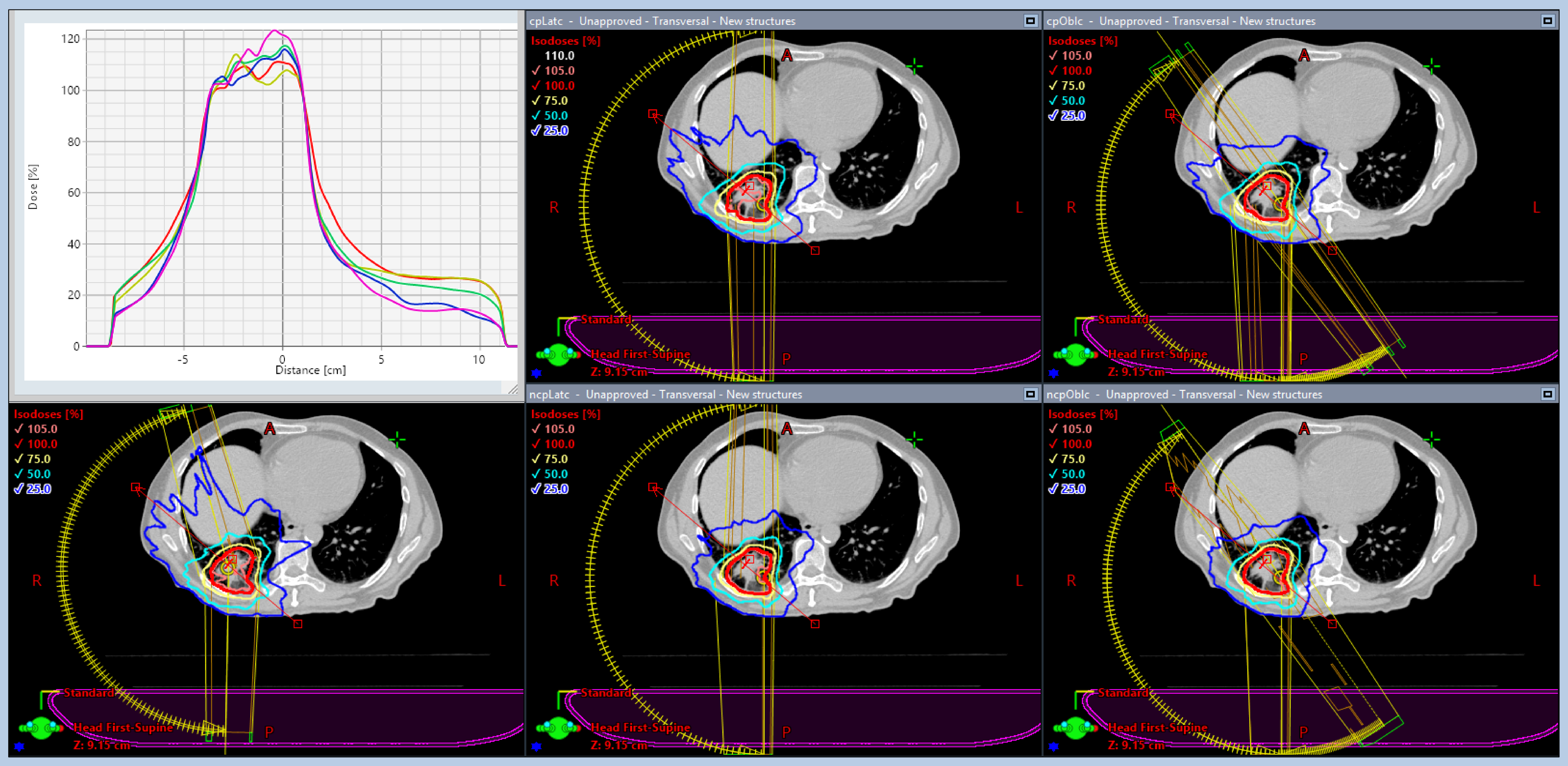

Fig 4. Dose profiles and distributions are shown for a representative case. Top row from left to right: Dose profiles (left), cpLat (gold) and cpObl (green). Bottom row from left to right: clinical (red), ncpLat (blue) and ncpObl (magenta).

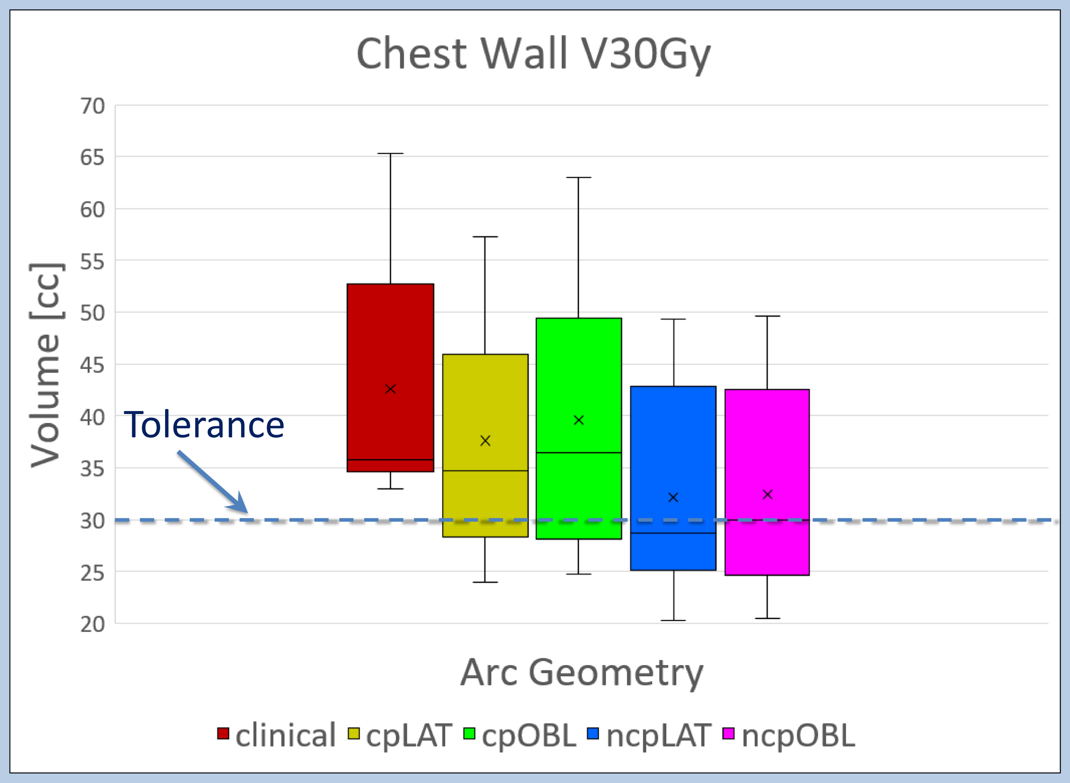

Fig 5. Chest wall V30Gy > 30 cc is associated with toxicity. These cases may require > fractionation.

ARC GEOMETRY	CLINICAL		CP LATERALS		CP OBLIQUES		NCP LATERALS		NCP OBLIQUES	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
ISODOSE/PTV										
CI100%	1.07	0.15	0.97	0.02	0.97	0.02	0.97	0.01	0.96	0.01
CI75%	1.90	0.29	1.62	0.07	1.61	0.07	1.55	0.06	1.54	0.06
CI50%	3.92	0.69	3.35	0.28	3.33	0.30	2.98	0.23	2.95	0.23
CI25%	14.1	4.0	12.3	2.4	11.2	2.5	10.1	2.0	9.5	1.8
CHEST WALL										
V30Gy [cc]	42.6	10.9	37.6	10.5	39.6	12.4	32.2	10.0	32.4	10.1
ESOPHAGUS										
Max [Gy]	15.0	10.7	14.7	10.1	14.0	9.9	13.5	10.4	13.3	10.5
GREAT VESSELS										
Max [Gy]	24.0	20.2	22.4	17.9	21.7	18.4	21.3	18.7	21.2	19.5
HEART*										
Max [Gy]	18.2	10.8	15.8	10.5	14.9	9.9	15.5	10.6	14.8	10.1
V20Gy [%]	0.3	0.6	0.4	0.9	0.2	0.6	0.3	0.9	0.2	0.5
V10Gy [%]	6.6	11.8	7.4	13.8	3.4	6.1	6.8	13.6	3.2	6.0
V5Gy [%]	23.8	23.5	23.0	25.8	19.2	20.3	19.6	27.0	15.9	20.7
LUNGS										
V20Gy [%]	6.1	4.3	5.7	4.1	5.3	3.8	5.2	3.9	5.0	3.8
V13.5Gy [%]	9.1	5.2	9.0	5.1	8.1	4.7	8.2	5.3	7.6	4.7
V12.5Gy [%]	9.8	5.3	9.8	5.3	8.7	4.7	8.9	5.5	8.1	4.9
SPINAL CORD										
Max [Gy]	12.8	5.3	11.8	3.8	11.7	3.9	12.0	4.0	12.2	4.0
TRACHEA										
Max [Gy]	2.0	2.7	1.8	2.4	1.8	2.5	2.2	2.8	2.1	2.7
MONITOR UNITS										
Plan Total	2723	346	2175	198	2052	199	2553	350	2477	325

Table 1. Dose conformity, OAR doses and monitor units. *Left-sided tumors.

CONCLUSIONS

- Arc geometry has a substantial effect on lung SBRT plan quality.
- Non-coplanar arcs are better at sparing healthy tissues than coplanar arcs.
- Further improvements are possible by crafting oblique arcs to avoid OARs.
- Commercial software permits safe implementation.

REFERENCES

1. Xiao Y, et al. IJROPB. 2009;73(4):1235-1242.
2. Lim D, et al. Acta Onc. 2009;49(2):219-224.
3. McGrath S, et al. ROJ. 2010;95(2):153-157.

ACKNOWLEDGEMENTS

- Special thank you to the dosimetrists, physicists and physicians at Emory for training on SBRT treatment planning.
- Special thank you to the SIU-Carbondale faculty and staff, especially Program Director Dr. Scott Collins.