Escalating Stereotactic Body Radiotherapy (SBRT) Dose in the Treatment of Large (> 5 cm) Lung Tumors via a Novel Dynamic Conformal Arc (DCA)-based SIB-VMAT

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INTRODUCTION & AIM

- Treating large (> 5 cm) lung tumors with ablative SBRT doses is challenging given the concern for morbidity.
- We present a novel dynamic conformal arc (DCA)-based[1] simultaneous integrated boost (SIB) VMAT-SBRT planning technique with flattening filter free (FFF) beams.
- This fast, safe, and effective method allows for dose escalation while sparing organs at risk (OAR).

METHOD

- Six patients with large (mean = 6.9 cm, range: 6.1-7.7 cm, diameter) solitary stage II non-small-cell lung cancer (NSCLC) tumors underwent SBRT of 40-50 Gy to the planning target volume (PTV) in 5 fractions.
- 3-6 non-coplanar VMAT arcs (clinical VMAT, isocenter placed at tumor center) with 6X-FFF beams.
- Treatments were re-planned using 3-partial arcs (at 0, ±15º, couch kicks) for 60 Gy to the gross target volume (GTV) and 50 Gy to the PTV in 5 fractions using a novel dynamic conformal arc (DCA) based VMAT technique (DCA-VMAT) with isocenter placed at patient midline.
- DCA-VMAT plans were recalculated using DCA-based dose with user-controlled field aperture shape before VMAT optimization.
- Clinical VMAT and DCA-VMAT plans were compared for target dose, OAR dose, mean biological effective dose (BED10, with α/β = 10 Gy), and treatment efficiency.

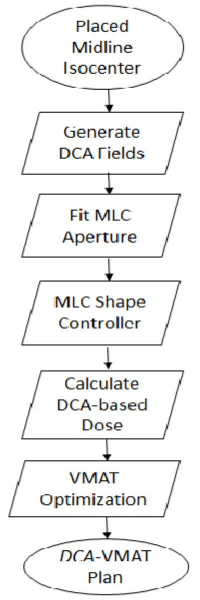

Fig. 1. Proposed workflow of DCA-VMAT treatment planning technique for large (> 5.0 cm) lung SBRT.

RESULTS

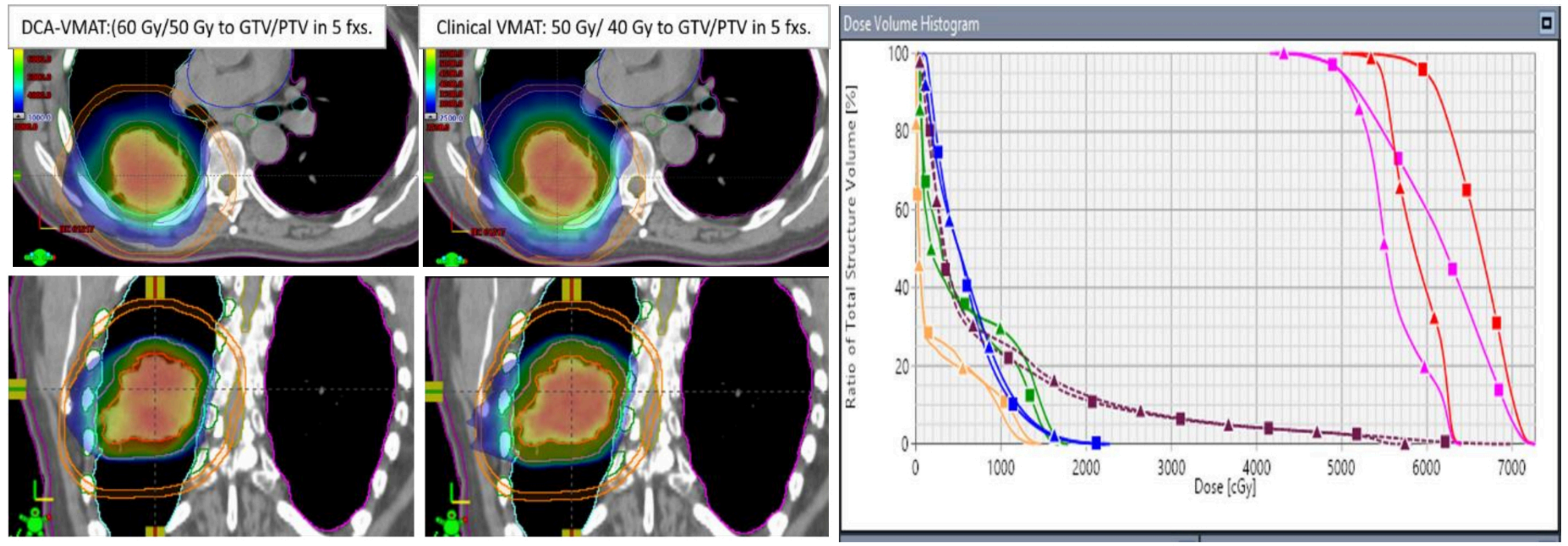

Fig. 2. Left, Axial and coronal views of isodose colorwash for an example patient (tumor size, 7.2 cm in diameter) planned (DCA-VMAT plan: 60 Gy/50Gy to GTV/PTV in 5 fractions) vs Center, clinical VMAT plan: 50 Gy in 5 fractions for PTV with 20% hot spots at the GTV). On the Right, triangles DVHs for clinical VMAT plan and squares DVHs for DCA-VMAT plan. With DCA-VMAT, higher values of mean GTV and PTV dose levels were achieved: corresponding GTV (BED10 = 153 Gy) to PTV (BED10 =136 Gy), while escalating hypoxic tumor center dose of additional 10 Gy compared to clinical VMAT plan and maintaining intermediate dose spillage, see D2cm (see orange ring), all other critical structures (yellow, spinal cord; green, ribs; blue, heart, and brown, normal lung) doses were also lower including normal lung doses. See dosimetry data in table 1 below for all 6 patients. Triangles Clinical VMAT vs Squares DCA-VMAT. ~1 Gy less mean lung dose using DCA-VMAT was obtained.

Table1. Tumor doses, maximal dose to organs & treatment parameters (n = 6 pts, PTV size = 6.1 to 7.7 cm)

Parameters	Clinical VMAT (40-50 Gy in 5 fxs)	DCA-VMAT (60 Gy/50 Gy to GTV/PTV in 5 fxs)
GTV (BED10, Gy)	112.7 ± 10.0	144 ± 10.7
PTV (BED10, Gy)	92.5 ± 5.1	127.2 ± 8.0
MLD (Gy)	7.9 ± 1.8	7.5 ± 1.6
V20 (%)	13.8 ± 4.2	12.3 ± 4.1
V5 (Gy)	31.8 ± 5.8	30.9 ± 5.4
Spinal cord (Gy)	12.5 ± 1.6	12.5 ± 2.4
Esophagus (Gy)	17.7 ± 2.9	18.3 ± 3.2
Heart (Gy)	33.9 ± 13.3	32.7 ± 13.3
Ribs (Gy)	48.2 ± 9.5	46.5 ± 10.7
Skin (Gy)	23.9 ± 2.3	23.1 ± 2.9
Total # of MU	2817 ± 437	2095 ± 254
Beam-on time (min)	2.01 ± 0.31	1.5 ± 0.18

SUMMARY & CONCLUSIONS

- Compared to clinical VMAT, DCA-based SIB-VMAT plans averaged higher hypoxic tumor center dose [144 Gy vs. 113 Gy (BED10)]; and PTV dose [127 Gy vs. 92.5 Gy (BED10)].
- DCA-VMAT provided tighter radiosurgical dose-distribution and similar or lower OAR doses including V20 & MLD.
- Lower total number of monitor units and small beam modulation factor reduced average beam on time by 0.51 min ($p < 0.001$), (maximum up to 0.90 min) - enabling faster treatment with higher dose to large tumor.
- Combining DCA-based SIB-VMAT technique with midline-isocenter position, provided excellent plan for large lung tumors by escalating hypoxic tumor center dose, reduced intermediate dose-spillage and maintained OAR dose with faster treatment delivery.
- With less MLC modulation through the target, DCA-based SIB-VMAT plans minimized small-field dosimetry errors and perhaps MLC interplay-effects.
- ***Major advantages of utilizing patient-midline isocenter were***: 1) avoid shifting patient during daily conebeam CT once set up at the machine, 2) get larger degrees of on-coplanar arcs (±15º couch kicks) without colliding gantry heard with the patients, and (3) get better target coverage by not limiting by 180º gantry clearance, posteriorly.
- If available, DCA-based SIB-VMAT planning is recommended for SBRT of large lung tumors.

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REFERENCES

1. Pokhrel D, Visak J, Sanford L. A novel and clinically useful dynamic conformal arc (DCA)-based VMAT planning technique for lung SBRT. J Appl Clin Med Phys. (2020); 1-10

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