Development and Clinical Validation of a Robust Knowledge-based Planning Model for SBRT of Centrally Located Tumors

J. Visak, MS [1], R.C. McGarry MD, PhD [1], M. Randall, MD [1] and D. Pokhrel, PhD [1]

1University of Kentucky, Medical Physics Graduate Program, Department of Radiation Medicine, Lexington, Kentucky

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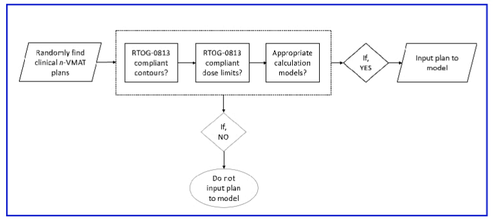
INTRODUCTION & AIM

- SBRT for early stage localized non-small cell lung cancer (NSCLC) has become a significant treatment option to traditional surgical intervention.[1,2]
- Generating an optimal SBRT treatment using a VMAT approach require multiple iterations and heavily depends on a planner's skill subjecting to inter-planner variability. [3,4]
- Automation of inverse planning via knowledge-based planning (KBP) aims to remove inter-planner variability, improve plan quality and decrease planning time. [5]
- **To develop a robust and adaptable knowledge-based planning (KBP) model with commercially available RapidPlan™ for early-stage, centrally-located non-small-cell lung tumors (NSCLC) treated with stereotactic body radiotherapy (SBRT) and improve a patient's 'simulation to treatment' time.**

METHODS

- KBP model was trained using 86 clinically treated non-coplanar volumetric modulated arc therapy (n-VMAT) lung SBRT plans with delivered prescriptions of 50 or 55 Gy in 5 fractions.
- Another twenty independent clinical n-VMAT plans were used for validation of model.
- KBP and n-VMAT plans were compared via RTOG–0813 protocol compliance criteria for conformity (CI), gradient indices (GI), dose to organs-at-risk (OAR), treatment delivery efficiency and accuracy.
- KBP plans were re-optimized with larger calculation grid size (CGS) of 2.5 mm to assess feasibility of rapid adaptive re-planning.



RESULTS

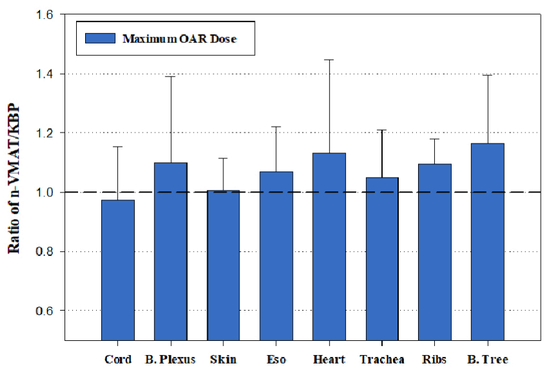


Fig 1. Ratio of clinical n-VMAT plans to KBPs of maximal dose to OAR compared to 20 lung SBRT cases used for validation. Prescription was 50 or 55 Gy in 5 fractions. . KBP model was able to spare maximum rib dose by 9% correlating an absolute average difference of 3.36 Gy (maximum up to 9.67 Gy). Maximal dose to bronchial tree was reduced by 16% translating to an absolute average of about 1.0 Gy less with KBPs while predicting similar dose to spinal cord.

Location	Patient Pop.	Dose (50/55 Gy)	PTV Size (cc)
Overall	n = 20	(16/4)	30.8 ± 22.5 (7.3-76.5)
RLL	n = 6	(6/0)	23.6 ± 16.9 (7.5-58.9)
RUL	n = 6	(4/2)	30.0 ± 23.8 (7.3-71.7)
LLL	n = 3	(3/0)	25.5 ± 9.6 (12.0-33.1)
LUL	n = 5	(3/2)	43.6 ± 26.5 (10.9-76.5)

Table 1. Patient cohort and tumor characteristics for validation of this comprehensive KBP-model. Overall, the patient cohort and each tumor geographical location and tumor sizes are presented as a total number (n) and mean ± SD (range)

Parameter	KBP	n-VMAT	p-value
CI	1.04 ± 0.037 (1.00 – 1.11)	1.01 ± 0.04 (0.97 – 1.17)	**p = 0.001**
GI	3.93 ± 0.94 (3.10 – 6.53)	4.19 ± 0.68 (3.38 – 6.02)	**p < 0.004**
D_{2cm} (%)	52.20 ± 4.00 (43.0 – 58.5)	52.1 ± 5.65 (46.0 – 70.3)	p = 0.95
GD (cm)	0.98 ± 0.19 (0.72 – 1.35)	1.08 ± 0.21 (0.78 – 1.62)	**p < 0.001**

Table 2. Evaluation of the conformity index and gradient indices for all 20-lung SBRT patients that were generated via KBP model for validation. Mean value ± SD (range) and p-values were reported. n. s. = not significant. Significant values are highlighted in bold.

Metric	KBP	n-VMAT	p-value
Total MUs	3432 ± 262 (2553–4639)	3171 ± 514 (2262–4104)	**p < 0.03**
Mod. Factor	3.36 ± 0.44 (2.53–4.64)	3.11 ± 0.47 (2.26–3.86)	**p < 0.03**
BOT (min)	2.45 ± 0.34 (1.81–3.31)	2.27 ± 0.37 (1.62–2.93)	**p < 0.03**
2%/2mm Pass rate	94.4 ± 2.7 (90.6–100.0)	95.4 ± 2.3 (90.9–99.4)	p = 0.11

Table 2.Treatment delivery efficiency and accuracy of KBP with respect to clinical n-VMAT plans. Mean value ± SD (range) and p-values were reported for both KBP and n-VMAT plans. n. s. = statistically not significant. Significant values are highlighted in bold.

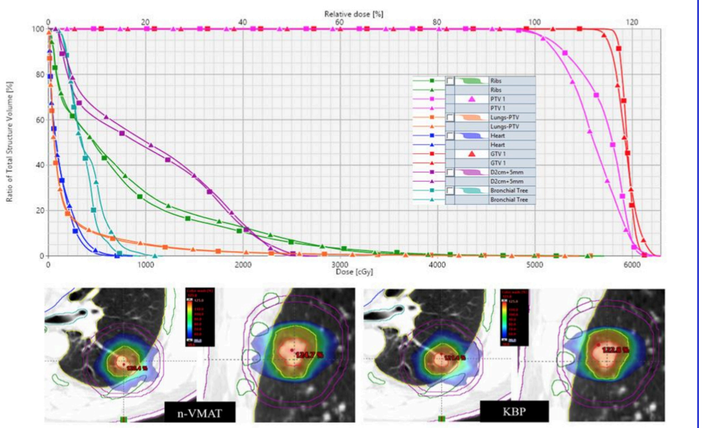


Fig 2. Dose volume histogram comparison and corresponding axial and coronal views of radiosurgical-isodose distributions for example clinical n-VMAT plan (bottom left) and the corresponding KBP plan (bottom right) are shown including the target coverage (for both PTV and GTV).

CONCLUSIONS

- Knowledge based plans were able to provide similar or better target coverage than clinical n-VMAT plans.
- Dose to normal lung was tracked using mean lung dose, and the volume receiving 5 Gy (V5) 10 Gy (V10) and 20 Gy (V20) or more and was found to be on average lower for all KBPs.
- Our study showed ipsilateral brachial plexus, esophagus, heart, trachea and bronchial tree received an insignificant average lower dose in KBPs compared to the clinical n-VMAT plans.
- KBPs on average presented an insignificant but slightly higher maximum dose to cord and skin.
- KBPs were not significantly more modulated as reflected in gamma analysis suggesting better plan quality is possible at minimal cost.

SUMMARY

- A knowledge-based planning (KBP) model for stereotactic body radiotherapy of centrally located early-stage NSCLC was developed using non-coplanar VMAT plans.
- KBPs were dosimetrically superior or equivalent.
- This robust model compliant with RTOG-0813 protocol is adaptable by radiotherapy clinics.
- Planning time was approximately 30 minutes, potentially shortening 'simulation to treatment' time to 3 working days.

REFERENCES

1. Benedict SH, Yenice KM, Followill D, et al. Stereotactic body radiation therapy: the report of AAPM Task Group 101. Med Phys. 2010;37(8):4078-4101.
2. Timmerman R, Paulus R, Galvin J, et al. Stereotactic body radiation therapy for inoperable early stage lung cancer. Jama. 2010;303(11):1070-1076.
3. Fogliata A, Reggiori G, Stravato A, et al. RapidPlan head and neck model: the objectives and possible clinical benefit. Radiat Oncol. 2017;12(1):73.
4. Berry SL, Ma R, Boczkowski A, Jackson A, Zhang P, Hunt M. Evaluating inter-campus plan consistency using a knowledge based planning model. Radiother Oncol. 2016;120(2):349-355.
5. Vanderstraeten B, Goddeeris B, Vandecasteele K, van Eijkeren M, De Wagter C, Lievens Y. Automated Instead of Manual Treatment Planning? A Plan Comparison Based on Dose-Volume Statistics and Clinical Preference. Int J Radiat Oncol Biol Phys. 2018;102(2):443-450.

CONTACT INFORMATION

Email: justin.visak@uky.edu or damodar.pokhrel@uky.edu