Fast Delivery Using Static Collimation in Lieu of Layer-by-Layer Collimation for the Treatment of Lung Targets Using Intensity Modulated Proton Therapy: A Dosimetric Evaluation

Michael T Prusator[1], Tiezhi Zhang[1], Baozhou Sun[1] and Tianyu Zhao[1]
1 Washington University School of Medicine, St. Louis, Missouri

Washington University in St.Louis School of Medicine

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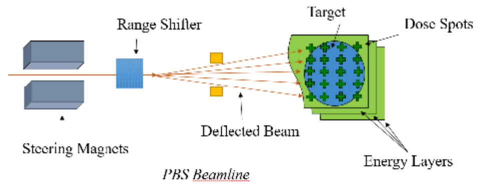
INTRODUCTION

A gantry-mounted pencil beam scanning system features ultra-fast energy layer switching and an adaptive aperture (AA), capable of layer-by-layer collimation. In mobile targets, fast energy layer switching could reduce interplay effects and enable treatment using deep inhalation breath hold (DIBH). However, despite the dosimetric advantage of the AA, the finite time to collimate energy layers increases field delivery time

AIM

The purpose of this study was to evaluate the feasibility of using a static aperture (SA) for lung treatments in lieu of layer-by-layer collimation to take advantage of fast delivery



In a pencil beam scanning (PBS) system, deflected pencil beams paint dose over the target. Collimation reduces penumbra outside the target

METHOD

- Ten patients were selected with target sizes ranging from 7-425 cc
- Each were planned using the adaptive AA and static aperture SA and was optimized to achieve target coverage and spare normal tissues as much as possible
- The delivery time for each field in each plan was calculated and compared assuming a 50 ms and 1s energy layer switching time for the AA and SA, respectively.
- Dosimetrically, the SA and AA plans were compared at the dose points of V20 Gy and V5 Gy for lung, the heart and esophagus mean dose, and V98% coverage on the target.
- Normal tissue complication probabilities (NTCP) at the endpoints of lung fibrosis, cardiac mortality and clinical stricture of the esophagus were calculated and compared.

RESULTS

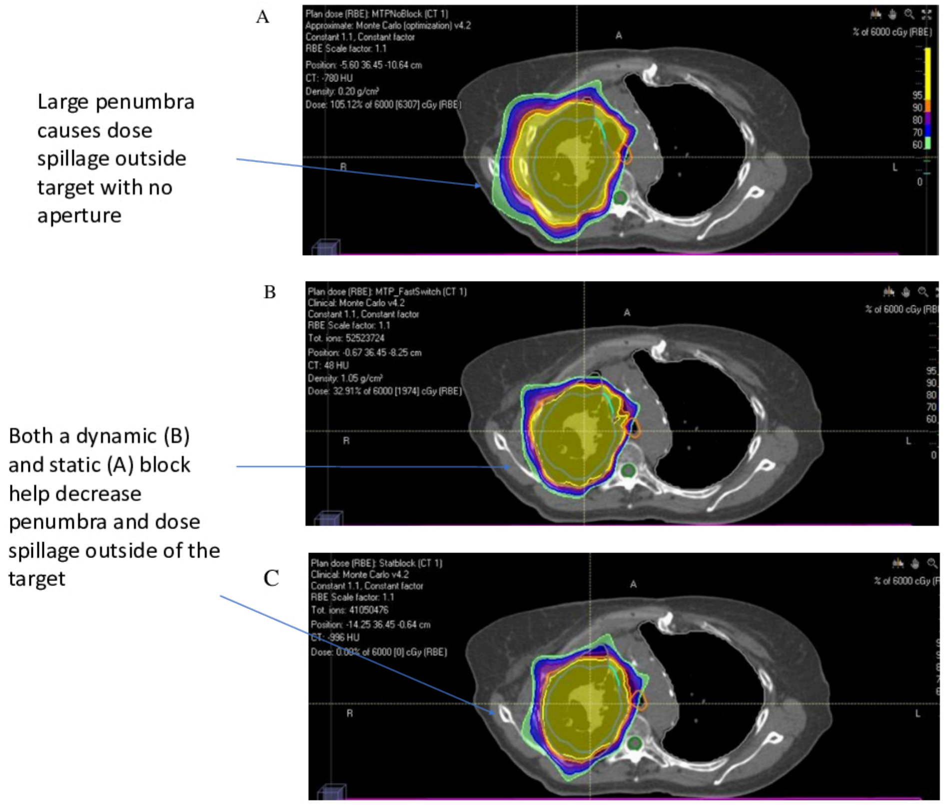


Figure 1. Cross sectional dose distribution for A) no aperture B) dynamic aperture and C) static block

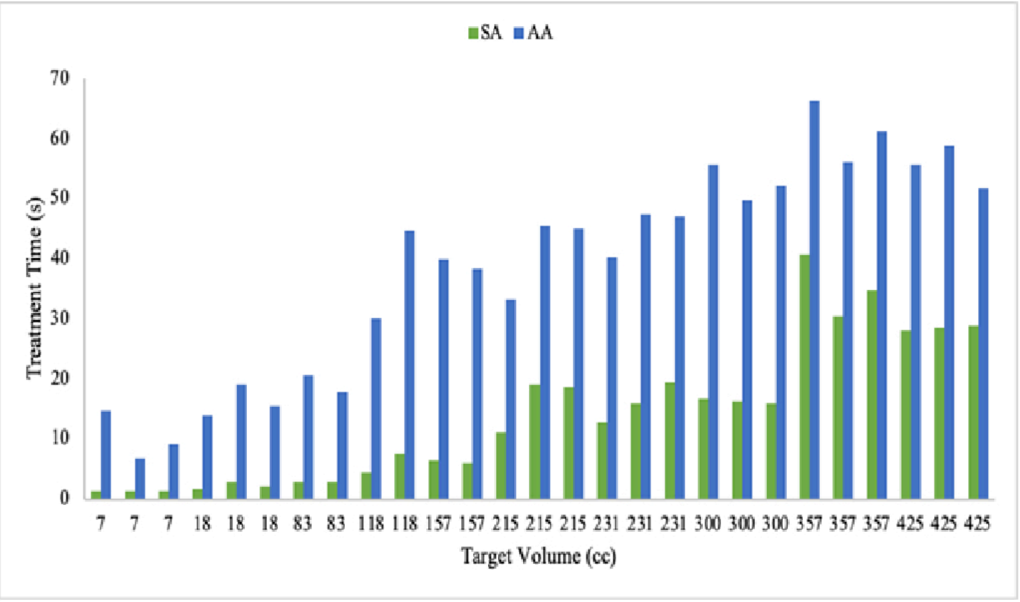


Figure 2. Calculated field delivery times using a SA and AA for each field for each of the ten patients evaluated

Patient	Heart		Lung-PTV		Esophagus	
	SA	AA	SA	AA	SA	AA
1	0%	0%	11%	13%	0%	0%
2	0%	0%	2%	3%	0%	0%
3	3%	3%	11%	12%	1%	2%
4	1%	1%	6%	7%	0%	0%
5	0%	1%	13%	16%	0%	0%
6	0%	0%	0%	0%	0%	0%
7	3%	3%	15%	15%	4%	3%
8	3%	3%	11%	12%	1%	2%
9	6%	6%	22%	20%	48%	48%
10	15%	16%	3%	2%	0%	0%

Figure 3. Calculated NTCP values for each of the plans evaluated for each patient

- Calculated field delivery times show an average of 30% less using the SA versus the AA. For target volumes less than 150 cc, a field could be delivered in less than 10 seconds using the SA, and under 20 seconds for volumes less than 300 cc. Figure 1 shows the calculated delivery time.
- The average absolute difference in the mean heart dose, esophagus dose, lung V5, and lung V20 between the plans for the two aperture techniques were 17.5 cGy, 62cGy, 1.8% and 0.9%, respectively. The PTV coverage of 98% prescription showed an average difference of only 0.64%.
- Calculated NTCP values showed absolute average differences of 0.6%, 0.2% and 1.3% for lung, heart and esophagus, respectively and are shown in Figure 2

CONCLUSIONS

The use of a SA technique can significantly reduce treatment field delivery times and does not seem to have a significant detrimental effect on the dosimetry. Based upon this data, it is believed that using a SA to treat mobile targets is clinically acceptable.

This suggests that the treatment of mobile targets using the compact PBS system has the potential to reduce interplay, as well as open the possibility to treat with DIBH up to large target volumes where it is assumed that a 20 second breath hold is achievable by most patients.

FUTURE STUDY

Future studies will include development of a workflow to treat real patients using the SA

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CONTACT INFORMATION

m.prusator@wustl.edu