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A Simple 3D AP-PA Solution for Multiple-Isocenter Total Body Irradiation

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ABSTRACT

Purpose: Although many advantages are associated with VMAT-TBI but there are some disadvantages such as time-consuming planning process and long treatment time . For the full-dose TBI, the effort to create the complicated VMAT plans can be justified, but for the low-dose TBI, it seems unnecessary to use such a sophisticated solution. This simplified 3D technique will offer much shorter planning time, faster treatment time, no PSQA required, and higher tolerance for setup uncertainties.

Methods: This 3D AP-PA solution utilizes multiple isocenters and overlapping AP/PA beams to deliver a desired dose distribution. Compared to VMAT fields, these big open AP/PA fields have the advantage of larger setup margins. An in-house python script for our treatment planning system (RayStation) was created to generate and optimize AP/PA fields with feathering overlaps. The script will create 5 feathering sub-fields for the junctions and reduce hot/cold spots by adding 2 more sub-fields for each beam.

Results: Two plans were generated with an anonymized patient's images. The first plan was prescribed to 2 Gy and the lungs was not spared. The second plan was prescribed to 12 Gy and the lung was spared. Both plans were compared to the VMAT-TBI plans generated with the same dose criteria. For the low-dose prescription without sparing the lungs, the dosimetric results from the VMAT-TBI and 3D AP-PA plans are very similar. For the high-dose prescription sparing the lungs, the dosimetric results from the VMAT-TBI plan is superior to the 3D AP-PA plan due to the chest walls above and below the lungs received insufficient dose.

Conclusion: The 3D AP-PA technique is a great solution for low-dose TBI patients.

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INTRODUCTION

Recently, a modern total body Irradiation method using volumetric-modulated arc technique (VMAT-TBI) has gained popularity. Many advantages are associated with VMAT-TBI, such as being able to treat the patient in a standard room, image the patient with cone-beam CT, superior control of dose distributions for targets and critical organs.

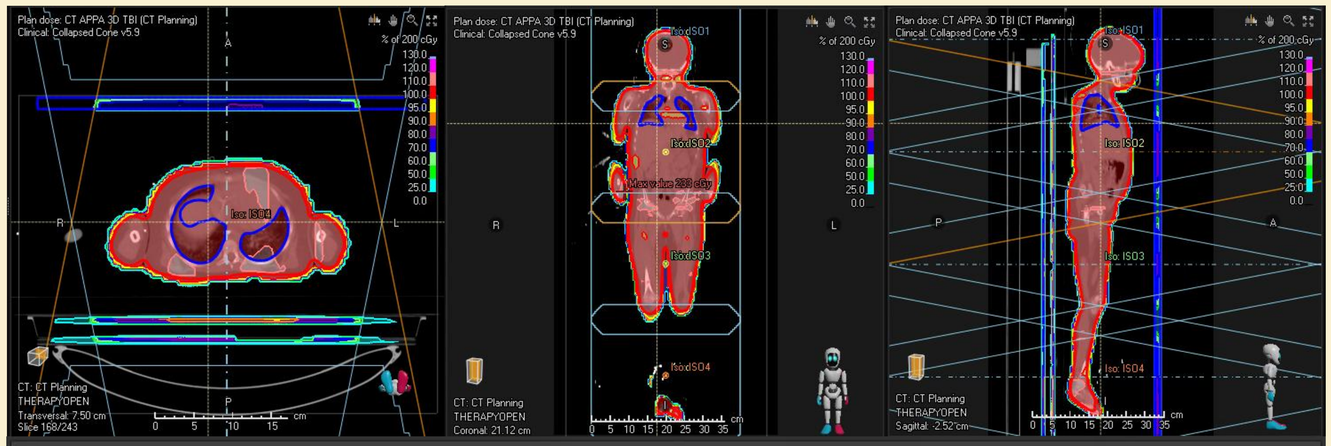
The disadvantages are higher requirement in planning capabilities including handling both HFS and FFS CT scans, time-consuming contouring and planning process, and longer treatment time. For the full-dose (12 Gy or more) TBI, the effort to create the complicated VMAT plans can be well worth it, but for the low-dose (2 - 4 Gy) TBI, it seems unnecessary to use such a sophisticated technique. We have simplified this treatment method by replacing all VMAT beams with AP/PA 3D fields.

The advantage of this simplified technique is not only the shorter planning time, also a faster treatment and higher tolerance for setup uncertainties. Based on our experience in VMAT-TBI, the hands, arms and legs are very difficult to reposition perfectly every time. .

METHODS AND MATERIALS

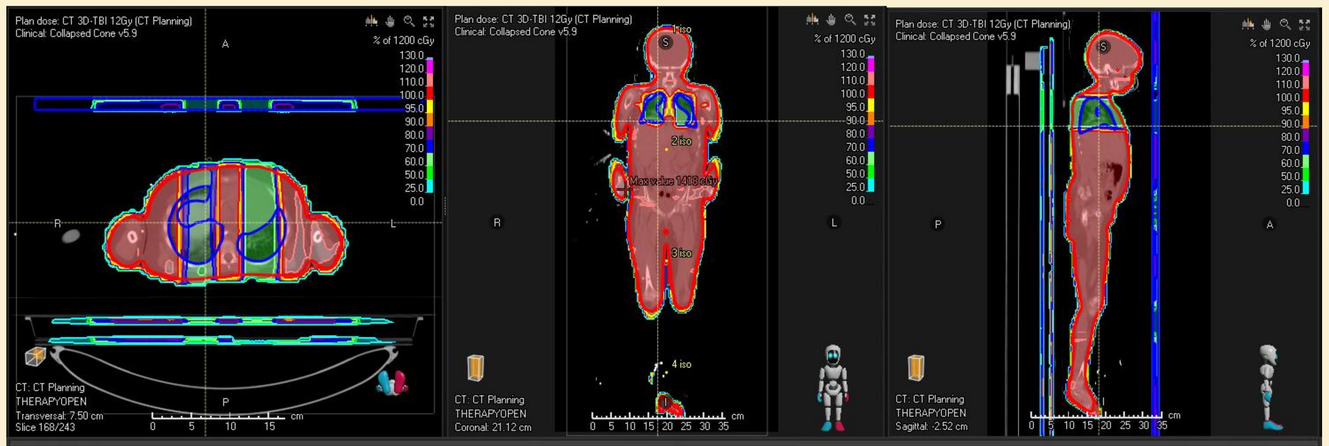
This simplified 3D AP-PA solution utilizes multiple isocenters and overlapping AP/PA beams to deliver a desired dose distribution to the whole body. To deliver sufficient dose in the buildup region of the anterior surface, an acrylic plate (1.5cm thick) is used for all AP beams.

Compared to VMAT fields, these big open AP/PA fields have the advantage of larger setup margins and shorter treatment time. However, designing these overlapping fields by either inversed or forward IMRT technique can be challenging. An in-house python script for our treatment planning system (RayStation) was created to generate and optimize AP/PA fields with feathering overlaps. The script will create 5 feathering sub-fields for the junctions and reduce hot/cold spots by adding 2 more sub-fields for each beam.



Priority	Dose	ROI/POI	Clinical goal	Value	Result	% outside grid
Association: Beam set '3D AP-PA TBI 2Gy' (5)						
1	Plan dose: 3D AP-PA TBI 2Gy (CT Planning)	PTV_Body-Total	At least 90.00 % volume at 200 cGy dose	97.03 %	✓	0 %
2	Plan dose: 3D AP-PA TBI 2Gy (CT Planning)	PTV_Body-Total	At least 95.00 % volume at 190 cGy dose	99.95 %	✓	0 %
3	Plan dose: 3D AP-PA TBI 2Gy (CT Planning)	PTV_Body-Total	At least 99.00 % volume at 180 cGy dose	100.00 %	✓	0 %
4	Plan dose: 3D AP-PA TBI 2Gy (CT Planning)	PTV_Body-Total	At most 10.00 % volume at 220 cGy dose	5.90 %	✓	0 %
5	Plan dose: 3D AP-PA TBI 2Gy (CT Planning)	External	At most 240 cGy dose at 0.00 % volume	233 cGy	✓	0 %

Figure 1: The dose distribution and dosimetric results of a 3D AP-PA TBI (2 Gy) plan. This plan utilized total of 4 isocenters with 4 pairs of AP-PA beams. A 1.5cm thick acrylic plate was used as a spoiler to increase the anterior surface dose. The goal was to achieve uniform dose for the whole body; lungs were not spared.



Priority	Dose	ROI/POI	Clinical goal	Value	Result	% outside grid
Association: Beam set '3D AP-PA TBI 12G' (6)						
1	Plan dose: 3D AP-PA TBI 12Gy (CT Planning)	PTV_Body-Total	At least 90.00 % volume at 1200 cGy dose	92.07 %	✓	0 %
2	Plan dose: 3D AP-PA TBI 12Gy (CT Planning)	PTV_Body-Total	At least 95.00 % volume at 1140 cGy dose	94.16 %	!	0 %
3	Plan dose: 3D AP-PA TBI 12Gy (CT Planning)	PTV_Body-Total	At least 99.00 % volume at 1080 cGy dose	94.84 %	!	0 %
4	Plan dose: 3D AP-PA TBI 12Gy (CT Planning)	PTV_Body-Total	At most 10.00 % volume at 1320 cGy dose	6.35 %	✓	0 %
5	Plan dose: 3D AP-PA TBI 12Gy (CT Planning)	Lungs_Total	At most 800 cGy average dose	755 cGy	✓	0 %
6	Plan dose: 3D AP-PA TBI 12Gy (CT Planning)	External	At most 1440 cGy dose at 0.00 % volume	1418 cGy	✓	0 %

Figure 2: The dose distribution and dosimetric results of a 3D AP-PA TBI (12 Gy) plan. This plan utilized total of 4 isocenters with 4 pairs of AP-PA beams. A 1.5cm thick acrylic plate was used as a spoiler to increase the anterior surface dose. The goal was to achieve uniform dose for the whole body and reduced the average lung dose to below 800 cGy

RESULTS & DISCUSSIONS

Two plans were generated with a 7-year-old patient's anonymized CT images. The first plan was prescribed to 2 Gy for single fraction, and the lungs was not spared. The second plan was prescribed to 12 Gy for 6 fractions, and the lung was spared.

Both plans were compared to the VMAT-TBI plans generated with the same dose criteria. For the low-dose prescription without sparing the lungs, the dosimetric results from the VMAT-TBI and 3D AP-PA plans are very similar. For the high-dose prescription sparing the lungs, the dosimetric results from the VMAT-TBI plan is superior to the 3D AP-PA plan due to the chest walls above and below the lungs received insufficient dose. .

CONCLUSIONS

The AP/PA technique provides advantages as larger setup margins, feathering junctions, and shorter delivery time.

REFERENCES

1. Grace Kim Memorial Grand Challenge: Advancing Total Body, Marrow, and Lymphoid Irradiation Treatment Planning (Grace Challenge) https://www.aapm.org/GrandChallenge/Grace/Default.asp.

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