Automatic Planning Script for Volumetric-Modulated Arc Therapy Total Body Irradiation (VMAT-TBI)

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INTRODUCTION

The Volumetric-Modulated Arc Therapy Total Body Irradiation (VMAT-TBI) utilizes multiple isocenters and overlapping VMAT/IMRT beams to achieve the desired dose distribution to the whole body. At our institution, each TBI patient received an upper-body HFS and lower-body FFS CT scans. The head and neck, thorax, and pelvis were planned with VMAT fields, and the lower extremities were planned with AP/PA IMRT fields (Fig.1). A full-body dose distribution was created by deformable registration and dose summation in our RayStation planning system.

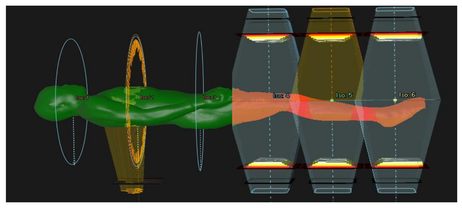

Fig 1: Our VMAT-TBI Technique includes VMAT arcs for upper body and AP/PA IMRT beams for lower body.

AIM

Streamline the planning workflow and achieve desired dose distribution for VMAT-TBI plans.

METHOD

An in-house python script in Raystation v10A and Ironpython v2.7 environment was created to generate and optimize AP/PA IMRT fields for the lower body of the TBI plan (Fig.2). The script can efficiently generate lower-body plans within 10 mins. Additional manual tweaking maybe required to polish the details.

Auto-Planning Workflow:

1) Setup isocenters with 30 cm separation.
2) Add AP and PA beams for each isocenters.
3) Create feathering sub-fields for each junction. (by Script)
4) Create ROI from high dose region. (by Script)
5) Create segments and block the high-dose ROI. (by Script)
6) Assign appropriate MU and calculate dose. (by Script)
7) Repeat step 4 – 6 until 110% volume < 10%.

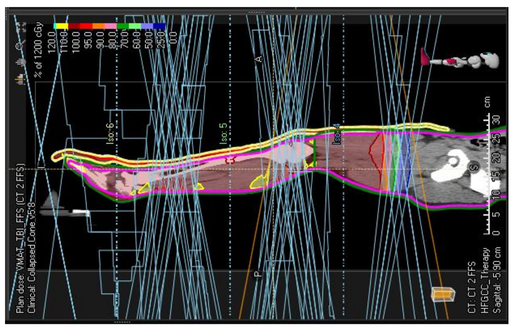

Fig 2: Auto-planning script created AP/PA IMRT fields

RESULTS

Compared to the traditional large-field TBI, many advantages are associated with the volumetric-modulated total body irradiation (VMAT-TBI) technique.

Major Advantages of VMAT-TBI:

- ***Easy Setup*** *– Recommended supplies include: whole-body board, head mask, vacuumed bag, knee sponge and bolus, and access for anesthesia (see Fig. 3). (No longer requires large standing frame, spoiler, lung blocks and large vault for extended distance treatments)*
- ***Better Dosimetry*** *– Control the dose distribution with state-of-the-art VMAT/IMRT optimizations. The dose uniformity and lung sparing are much superior to traditional AP/PA or Bilateral TBI (see Fig. 4 – 8)*
- ***Accurate Delivery*** *– Setup with surface guided system and verified position by CBCT immediately prior to deliver dose with VMAT/IMRT beams. Large overlap junction between isocenters to minimize field matching uncertainty.*

The auto-planning script has been implemented clinically on 5 recent TBI patients. Planning time decreased from 3 hours to less than 30 minutes for the lower body plan. The dose statistics of these 5 TBI plans met all our clinical goals. The max point doses are less than 120%, the V110% are less than 10% and the V100% are higher than 90%.

Fig 3: QFix Immobilization Devices for VMAT-TBI

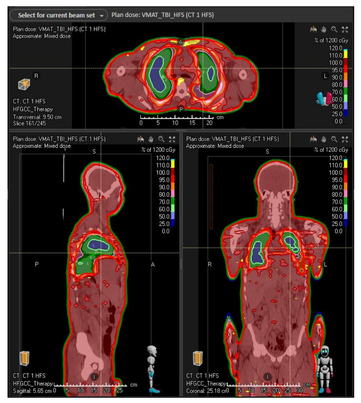

Fig 4: VMAT-TBI Dose Distribution

Fig 5: Traditional-AP/PA Dose Distribution

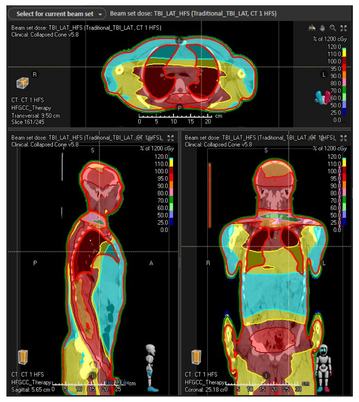

Fig 6: Traditional-RT/LT Dose Distribution

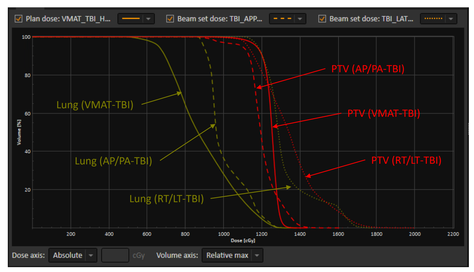

Fig 7: Dose Volume Histogram Comparison

Dose	ROI/POI	Clinical goal	Value	Result
Plan dose: VMAT_TBI_HFS (CT 1 HFS)	External	At most 1440 cGy dose at 0.03 cm³ volume	1434 cGy	✓
Plan dose: VMAT_TBI_HFS (CT 1 HFS)	Lungs_Total	At most 900 cGy average dose	893 cGy	✓
Plan dose: VMAT_TBI_HFS (CT 1 HFS)	PTV_5mm_FFS	At least 1200 cGy dose at 90.00 % volume	1215 cGy	✓
Plan dose: VMAT_TBI_HFS (CT 1 HFS)	PTV_5mm_FFS	At most 1320 cGy dose at 10.00 % volume	1311 cGy	✓
Plan dose: VMAT_TBI_HFS (CT 1 HFS)	PTV_5mm_FFS	At least 95.00 % volume at 1140 cGy dose	99.46 %	✓
Plan dose: VMAT_TBI_HFS (CT 1 HFS)	PTV_5mm_HFS	At least 1200 cGy dose at 90.00 % volume	1202 cGy	✓
Plan dose: VMAT_TBI_HFS (CT 1 HFS)	PTV_5mm_HFS	At most 1320 cGy dose at 10.00 % volume	1288 cGy	✓
Plan dose: VMAT_TBI_HFS (CT 1 HFS)	PTV_5mm_HFS	At least 95.00 % volume at 1140 cGy dose	97.29 %	✓
Plan dose: VMAT_TBI_HFS (CT 1 HFS)	PTV_5mm_WB	At least 95.00 % volume at 1140 cGy dose	97.72 %	✓
Plan dose: VMAT_TBI_HFS (CT 1 HFS)	PTV_5mm_WB	At least 1200 cGy dose at 90.00 % volume	1205 cGy	✓
Plan dose: VMAT_TBI_HFS (CT 1 HFS)	PTV_5mm_WB	At most 1320 cGy dose at 10.00 % volume	1294 cGy	✓

Fig 8: VMAT-TBI can easily meet all clinical goals

CONCLUSIONS

Evidently, it is feasible to deliver required dose distribution with VMAT arcs to the whole body. However, the requirement of positioning accuracy for a VMAT delivery is much higher than an AP/PA delivery. Due to many degrees of freedom in the lower extremities, it's very difficult to re-position the whole legs to within 1 cm deviation from the plan.

The AP/PA IMRT field has the advantages of larger setup margins and shorter treatment time. However, designing these overlapping fields by either inversed or forward IMRT technique can be challenging. By using the automatic scripts, the planning of lower body TBI becomes easy and efficient. After the implementation of this auto-planning script, the planning time decreased from 3 hours to less than 30 minutes for the lower body plan. The upper body usually takes 2 – 4 hours to finish.

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