2nd PANHELLENIC CONGRESS OF MEDICAL PHYSICS
4-6 OCTOBER 2024| EUGENIDES FOUNDATION

Assessing VMAT based single-isocentric multi-focal dosimetry with an anthropomorphic polymer gel phantom: a quantitative evaluation

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1. Background-Aim

- The complexity of novel radiotherapy techiques require outstanding approaches in quality assurance.
- Single-isocentre Volumetric Modulated Arc Therapy (VMAT), has gained prominence due to its ability to simultaneously treat multiple brain lesions.
- VMAT allows for the delivery of highly conformal dose distributions, while sparing surrounding healthy tissues and also providing adequate dose coverage to the target volumes.

Figure 1. Volumetric Modulated Arc Therapy (VMAT)

- Accurate dosimetry verification is essential to ensure that treatment planning system (TPS) calculations reflect the true delivered doses.

Aim:

To compare Treatment Plan System (TPS) dose calculations and Polymer Gel Dosimetric (PGD) measurements for single-isocentric Volumetric Modulated Arc Therapy (VMAT), using a reusable anthropomorphic head PG dosimetric phantom.

2. Materials & Methods (I)

1. Use of Prime Phantom (RTsafe, Athens, Greece) with bone and soft tissue-equivalent materials for MR and CT imaging.
2. CT imaging (General Electric Revolution HD, GE Healthcare) of the Prime Phantom for treatment planning
3. Manual contouring of three asymmetrically distributed metastatic tumors by a Radiation Oncologist using Monaco TPS.
4. Development of a dual partial-arc VMAT plan with 6-MV photons (Elekta Infinity™ 6 MV) was formulated for the simultaneous irradiation of all three tumor sites, with a prescribed dose of 20 Gy to each tumor.

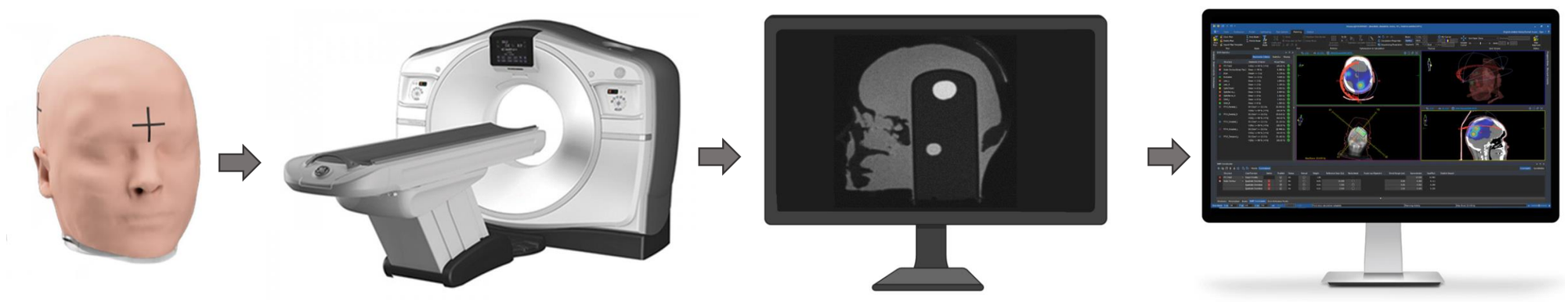

Figure 2. Step-by-Step Workflow from CT Imaging to VMAT Plan Development in Monaco TPS.

2. Materials & Methods (II)

5. Production of VIPET polymer gel under normoxic conditions.
6. Irradiation of Prime phantom with 6-MV photons.
7. Dose readout on a 1.5T clinical MRI scanner (MAGNETOM Symphony/Sonata Vision) using HASTE (Half-Fourier Acquisition Single-shot Turbo spin Echo) imaging sequences.
8. Analysis of 1D, 2D, and 3D Gamma Index (GI) and comparison between planned and measured relative dose distributions in terms of Dose Volume Histograms (DVHs) for all PTVs.

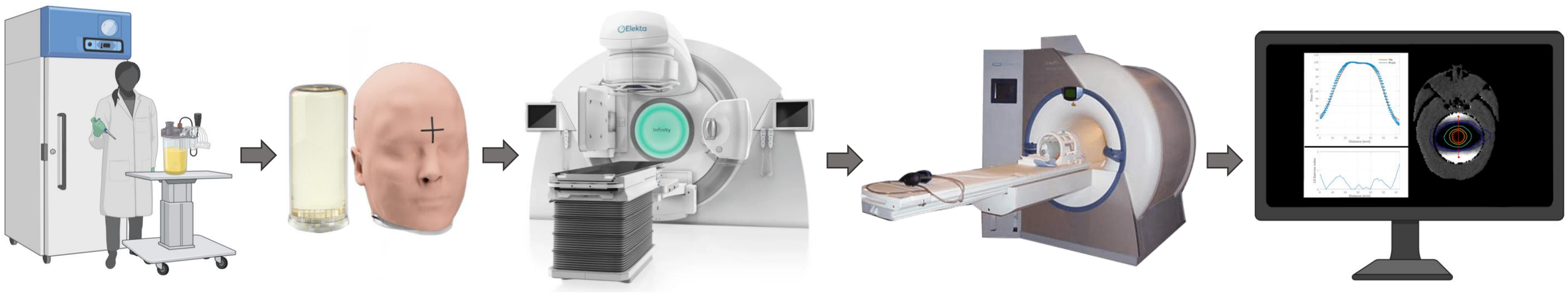

Figure 3. Step-by-Step Workflow from VIPET Polymer Gel Production to Dose Readout and Gamma Index Analysis.

3. Results (I)

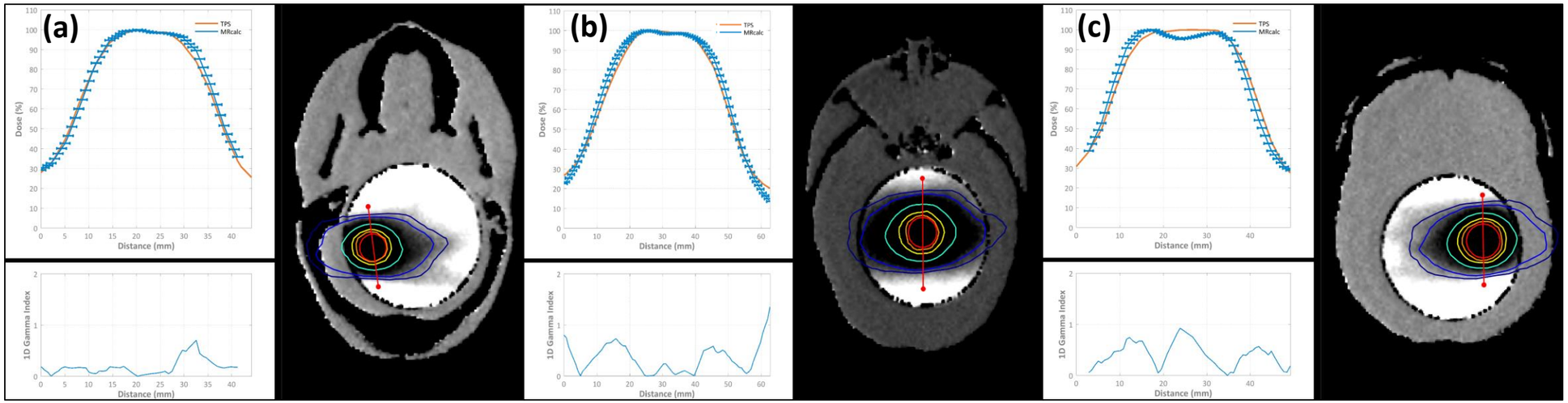

Figure 4. 1D Gamma Index Analysis. 1D dose profiles and 1D gamma index for (a) Bottom Tumor (Tumor 3), (b) Center Tumor (Tumor 1) and (c) Top Tumor (Tumor 2) in axial plane.

- 3D gel dosimetry, based on realistic anatomy, provided accurate spatial evaluation.
- 1D Gamma Index analysis showed high concordance between TPS and PGD dose measurements.

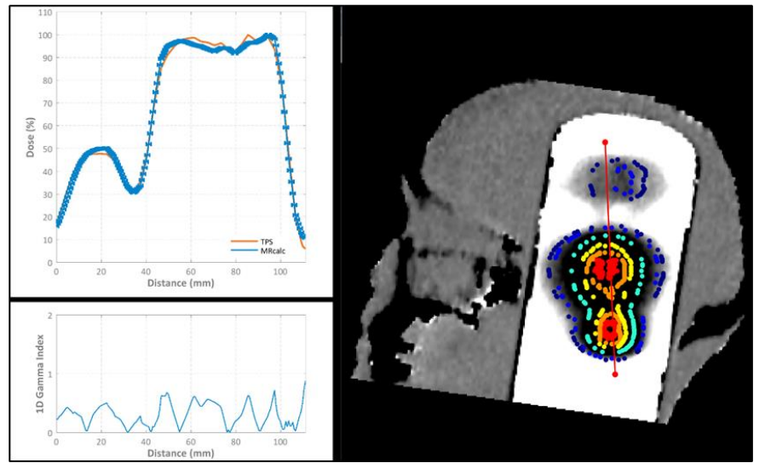

Figure 5. 1D Gamma Index analysis. 1D dose profiles and 1D gamma index in sagittal plane for all three tumors.

3. Results (II)

- 2D Gamma Index analysis showed high concordance between TPS and PGD dose measurements for all three tumor sites.

Table 1. Results for the 3D gamma index analysis, comparing gel-measured with the TPS dose distributions.

Structure	Passing criteria		Passing rate
	DD (%)	DTA (mm)	GI (%)
PTV 1	5	2	97.6
	3	2	97.7
PTV 2	5	2	98.4
	3	2	96.4
PTV 3	5	2	99.7
	3	2	96.3

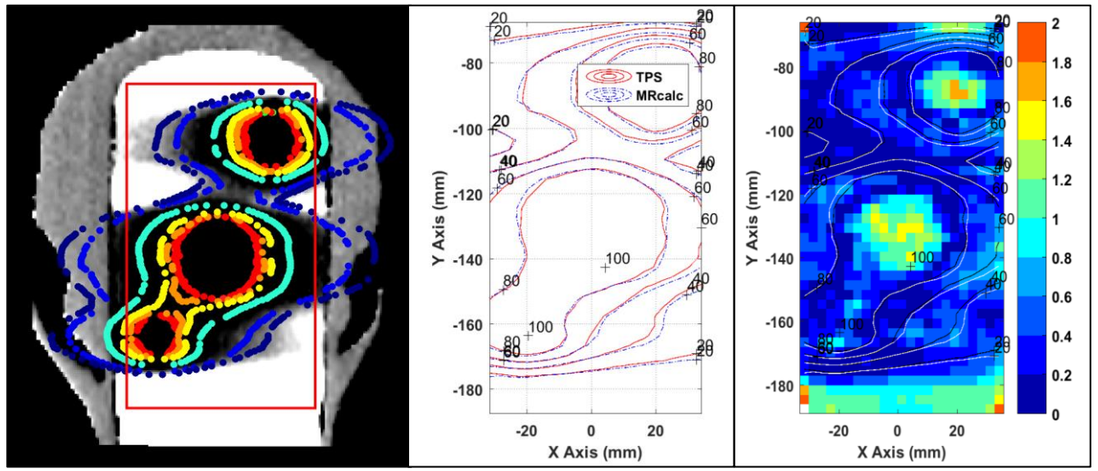

Figure 6. 2D Gamma Index analysis. 2D isolines and 2D gamma index maps in sagittal plane for all three tumors.

- 3D Gamma Index passing rate using a variety of criteria was greater than 95 %.
  - Dose Difference: 5% / Distance To Agreement: 2 mm
  - Dose Difference: 3% / Distance To Agreement: 2 mm

3. Results (III)

- DVH metrics were conducted between TPS and PGD relative dose distributions for the PTV-total.

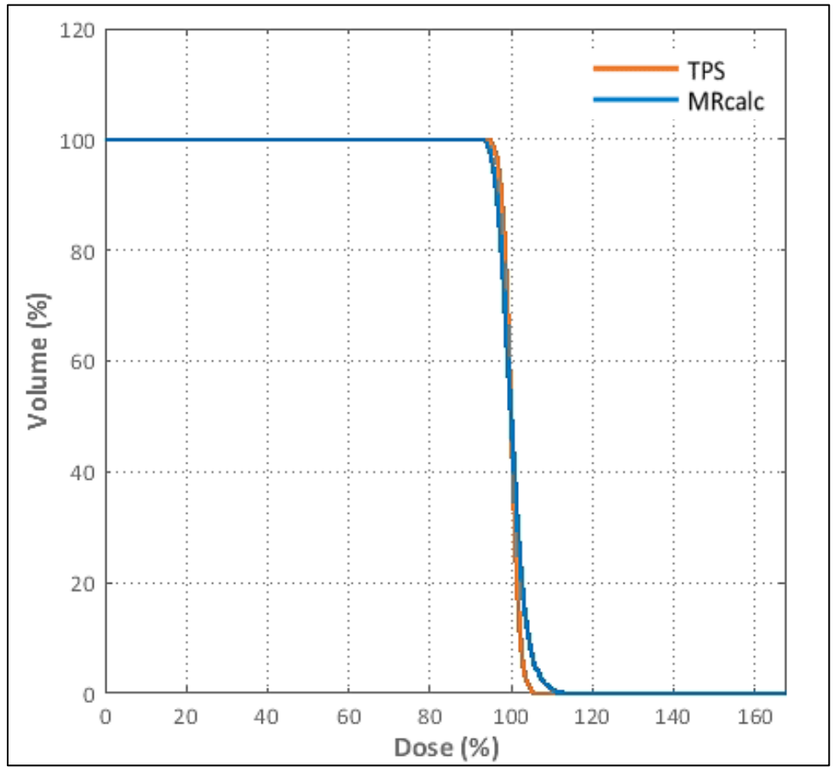

Figure 7. Relative Dose Volume Histogram derived from the calculated (TPS) and measured (MRcalc) dose distributions for PTV-total.

Table 2. Relative DVH results

Dose	TPS (%)	MRcalc (%)
D50	100.00	100.00
D95	96.83	95.57
Dmin	94.63	93.37
Dmax	105.54	112.64
Dmean	99.99	100.27

4. Conclusions

- The study demonstrated high concordance between TPS dose calculations and polymer gel (PGD) dosimetric measurements for single-isocentric VMAT applied on an anthropomorphic head phantom.
- 1D, 2D, and 3D gamma index analyses, consistently showed passing rates above 95% for clinical criteria.
- DVH comparisons indicated that the treatment plan satisfied the dose-volume constraints for all PTVs (95% isodose coverage) and an Area under curve difference of < 5%.
- The Prime Phantom, with its realistic tissue-equivalent properties, coupled with MRI-based gel dosimetry, provided a valuable tool for comprehensive 3D dose verification.
- The findings support the use of advanced dosimetric tools, like Polymer Gel dosimetry, in the quality assurance of VMAT and similar radiotherapy techniques.

5. References

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