Characterisation of synthetic CTs clinical quality: which gamma indices to evaluate in practice?

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Purpose/Objective

Brain synthetic Computed Tomography (sCT) generation from Magnetic Resonance Imaging (MRI) are state-of-the-art methods avoiding registration errors and offering an easier clinical flow. Large variability of gamma indices has been reported, ranging from 1%/1mm to 3%/3mm with dose thresholds between 0% and 90%. However, the Planning Target Volume (PTV) role remains unexplored, even though largely affecting pass rates. This study aim was to define relevant gamma indices for a pCT-based dosimetry, in the context of clinical trials set up, to standardize future clinical practices and move towards optimal patient care.

Material and Methods

The cohort was composed of 200 couples CT/T1 weighted MRI and 194 couples CT/enhanced T1 weighted MRI. A modified HighResNet neural network was trained and validated with 242 and 81 patients respectively. The testing cohort was composed of 71 patients, with PTV sizes comprised between ($1cm^3$; $300cm^3$), ($300cm^3$; $1000cm^3$), ($1000cm^3$; $2500cm^3$) for 38, 8, 25 patients respectively. Treatment techniques were either DYNamic conformal arc (DYNARC, 17 patients), 3D Conformal Radiation Therapy (3DCRT, 27 patients) or Volumetric Modulated Arc Therapy (VMAT, 27 patients). Dose was re-calculated on sCT with pencil beam (DYNARC patients) or collapsed cone (3DCRT and VMAT patients). The investigated gamma indices were global 1%/1mm with 0%, 10%, 20%, 50% and 80% dose thresholds, as well as local 1%/1mm with 0% and 10% dose thresholds. Spearman's tests were first performed between PTV volumes and gamma indices to

assess correlations between dose metrics and target volumes. Second, Spearman's tests were used to evaluate gamma indices correlation with the Mean Absolute Error (MAE) and Volumetric Dice Similarity Coefficient (VDSC), respectively computed in the head and bone regions.

Results

The global gamma index with 0% dose threshold resulted in absolute correlations larger than 0.65 for DYNARC and VMAT (Table 1), advantaging small PTV volumes. Global gamma index with 80% threshold was too restrictive since it avoided many meaningful high dose points. Global 1%/1mm gamma index with 50% dose threshold and local 1%/1mm with 10% dose threshold presented the lowest correlations to PTV volumes among the remaining candidates (Figure 1). Correlations of the former with MAE were intermediate for 3DCRT and VMAT (Table 1, $|\rho|>0.43$). Similarly, for local 1%/1mm gamma index with 10% dose threshold, intermediate correlations were observed with MAE and VDSC ($|\rho|>0.52$).

Conclusion

The complimentary global 1%/1mm and local 1%/1mm with 50% and 10% dose thresholds respectively are recommended for a reduced PTV bias dose evaluation. Future brain sCT studies should also report lesions volumes for valuable image quality analyses.

Table 1: Spearman's correlation coefficients and p-values between PTV volumes, gamma indices, MAE and VDSC

	Delivery technique	Correlation coefficient (p-value)
1%/1mm global threshold 0% & PTV	**DYNARC**	**-0.71 (0.0015)**
	3DCRT	0.093 (0.65)
	VMAT	**-0.65 (0.00012)**
1%/1mm global threshold 10% & PTV	**DYNARC**	-0.21 (0.42)
	3DCRT	0.32 (0.11)
	VMAT	-0.23 (0.23)
1%/1mm global threshold 20% & PTV	**DYNARC**	-0.13 (0.63)
	3DCRT	0.36 (0.068)
	VMAT	-0.081 (0.67)
1%/1mm global threshold 50% & PTV	**DYNARC**	**-0.53 (0.028)**
	3DCRT	0.38 (0.048)
	VMAT	-0.040 (0.84)
1%/1mm global threshold 80% & PTV	**DYNARC**	-0.48 (0.052**)**
	3DCRT	**0.44 (0.021)**
	VMAT	-0.068 (0.72)
1%/1mm local no threshold & PTV	**DYNARC**	0.18 (0.49)
	3DCRT	0.29 (0.14)
	VMAT	0.26 (0.18)
1%/1mm local threshold 10% & PTV	**DYNARC**	-0.26 (0.30)
	3DCRT	0.35 (0.075)
	VMAT	-0.14 (0.48)
1%/1mm global threshold 50% & MAE	**DYNARC**	-0.22 (0.39)
	3DCRT	**-0.58 (0.0014)**
	VMAT	**-0.43 (0.026)**
1%/1mm global threshold 50% & VDSC	**DYNARC**	0.15 (0.55)
	3DCRT	**0.52 (0.0054)**
	VMAT	0.34 (0.087)
1%/1mm local threshold 10% & MAE	**DYNARC**	**-0.52 (0.034)**
	3DCRT	**-0.60 (0.00084)**
	VMAT	**-0.72 (< 0.0001)**
1%/1mm local threshold 10% & VDSC	**DYNARC**	**0.54 (0.025)**
	3DCRT	**0.55 (0.0032)**
	VMAT	**0.74 (< 0.0001)**

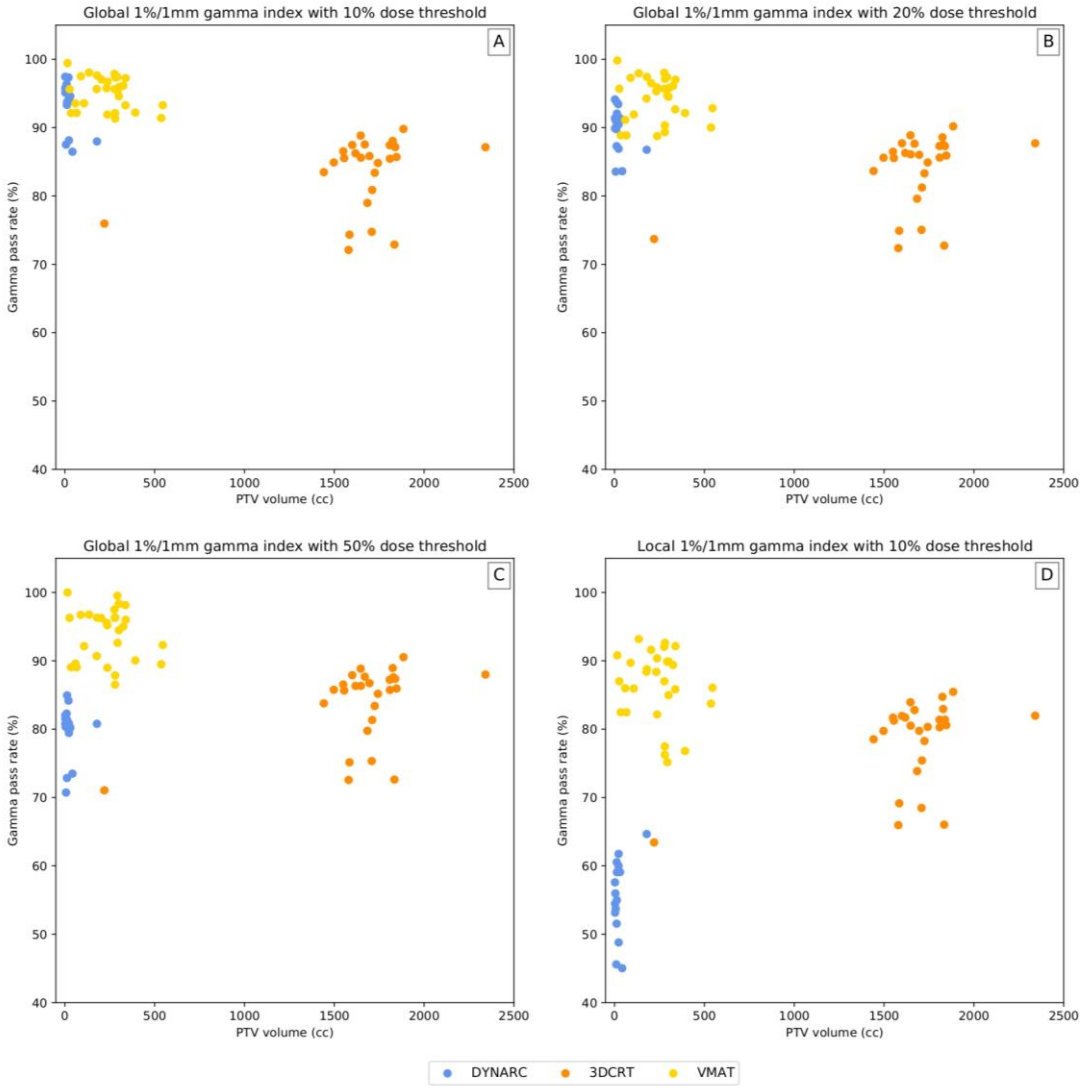

Figure 1: PTV sizes versus pass rates of the global 1%/1mm with 10% (A), 20% (B), 50% (C) dose thresholds and local 1%/1mm with 10% dose threshold (D)