Updating a Familiar Clinical Tool: Including Structures in Gamma Index Calculations

Cory Knill, M.S., Medical Physics Resident

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Workflow

Nelms Results ⟺ Compare ⟺ **Re-created Nelms Results** ⟺ Compare ⟺ **Structure Dependent Gamma Index Results**

Goal 1:

Verify results of Nelms et. al. paper

Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors[a]

Benjamin E. Nelms[b]
Canis Lupus LLC and Department of Human Oncology, University of Wisconsin, Merrimac, Wisconsin 53561

Heming Zhen
Department of Medical Physics, University of Wisconsin, Madison, Wisconsin 53705

Wolfgang A. Tomé
Departments of Human Oncology, Medical Physics, and Biomedical Engineering, University of Wisconsin, Madison, Wisconsin 53792

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Procedure 1:

- Re-create Nelms experiment (as closely as possible)
- Compare our results to Nelms

Goal 2:

Improve the IMRT QA gamma index analysis

Procedure 2:

- Develop a gamma comparison that uses planning structures
- Compare our results to the traditional gamma comparison method

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Nelms Procedure

Induced Errors

Machine	MLC Transmission	Penumbra @ 10cm depth
1(original)	T	P
2	**1/2T**	P
3	**2T**	P
4	T	**~1.5 P**
5	T	**~2.0 P**

Original Machine

4 Modified Machines

IMRT QA Calculated

QA Pass Rate

IMRT QA “Measured”

Correlating Pass Rate & Dose Differences

3D Patient Dose

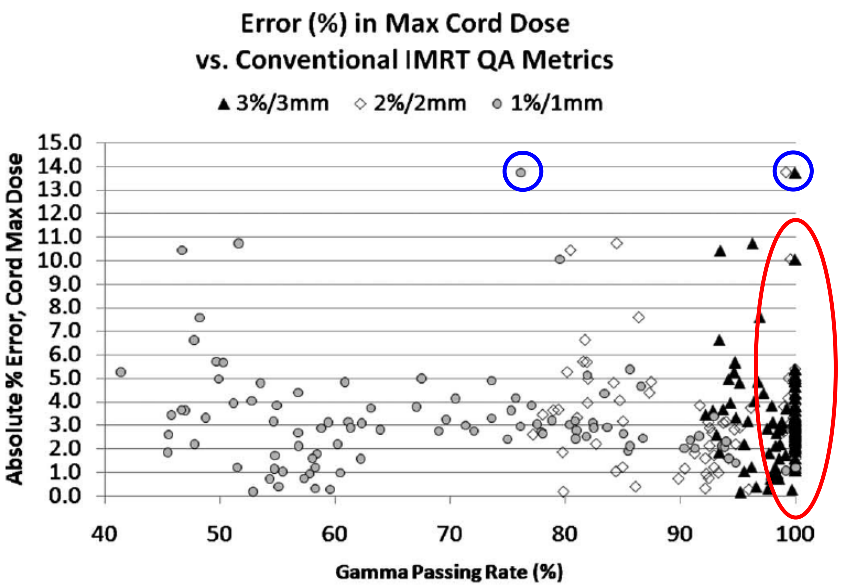
Dose Differences

3D Patient Dose

Comparing Results

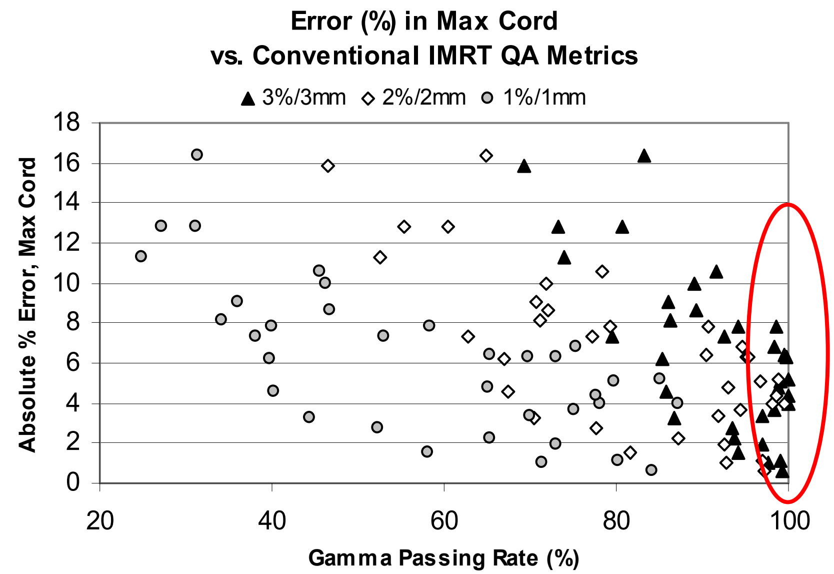
Spinal Cord Difference vs. QA Pass Rate

Nelms



	Spinal Cord D1cc error
IMRT QA Criteria	Pearson r-value
3%/3mm	-0.183
2%/2mm	-0.141
1%/1mm	-0.130

Our Results



	Spinal Cord Max error
IMRT QA Criteria	Pearson r-value
3%/3mm	-0.717
2%/2mm	-0.720
1%/1mm	-0.750

Multiple 100% passing results reduce the correlation

Outliers reduce the correlation

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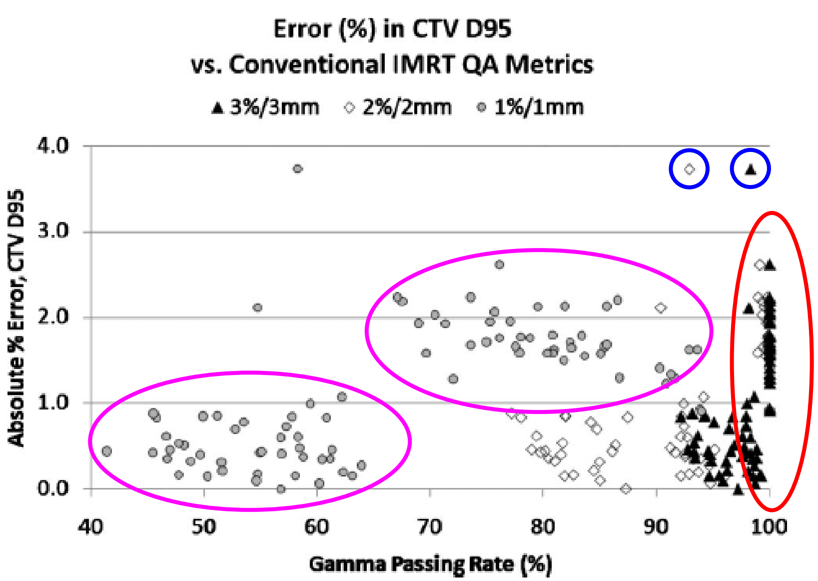
Comparing Results

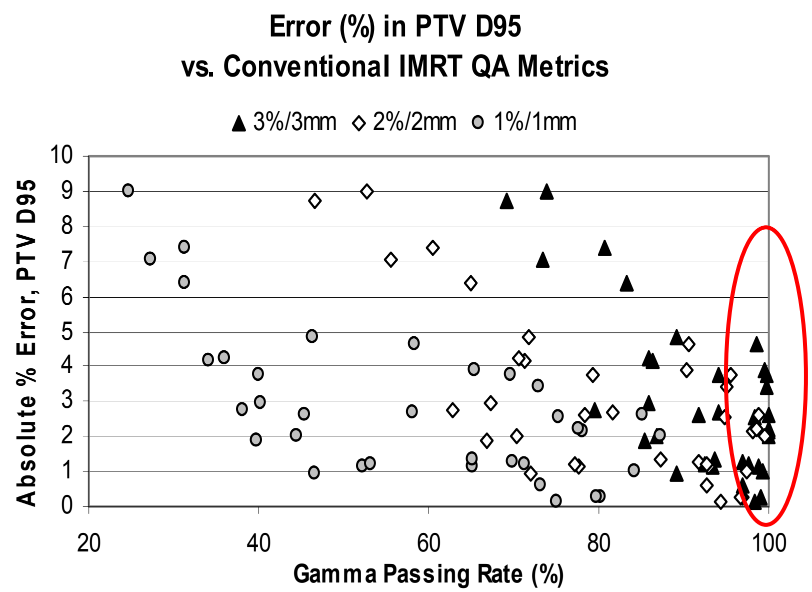
CTV/PTV D95 Difference vs. QA Pass Rate

Nelms



	CTV D95 error
IMRT QA Criteria	Pearson r-value
3%/3mm	0.604
2%/2mm	0.653
1%/1mm	0.619

Our Results



	PTV D95 error
IMRT QA Criteria	Pearson r-value
3%/3mm	-0.729
2%/2mm	-0.703
1%/1mm	-0.711

Multiple 100% passing results reduce the correlation

Outliers reduce the correlation

Two data groups could affect the correlation

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Conclusion

1. The re-created Nelms experiment yielded much better results then those originally published.
2. Institutions should be encouraged to perform this experiment to determine whether Nelm's results translate to their own clinical setup.

Important Study Differences

	Nelms	Exp.
Technique	Step-and-Shoot	Dynamic
TPS	Pinnacle	Eclipse
Target Volume	CTV	PTV
DVH Comparison	3DVH	TPS

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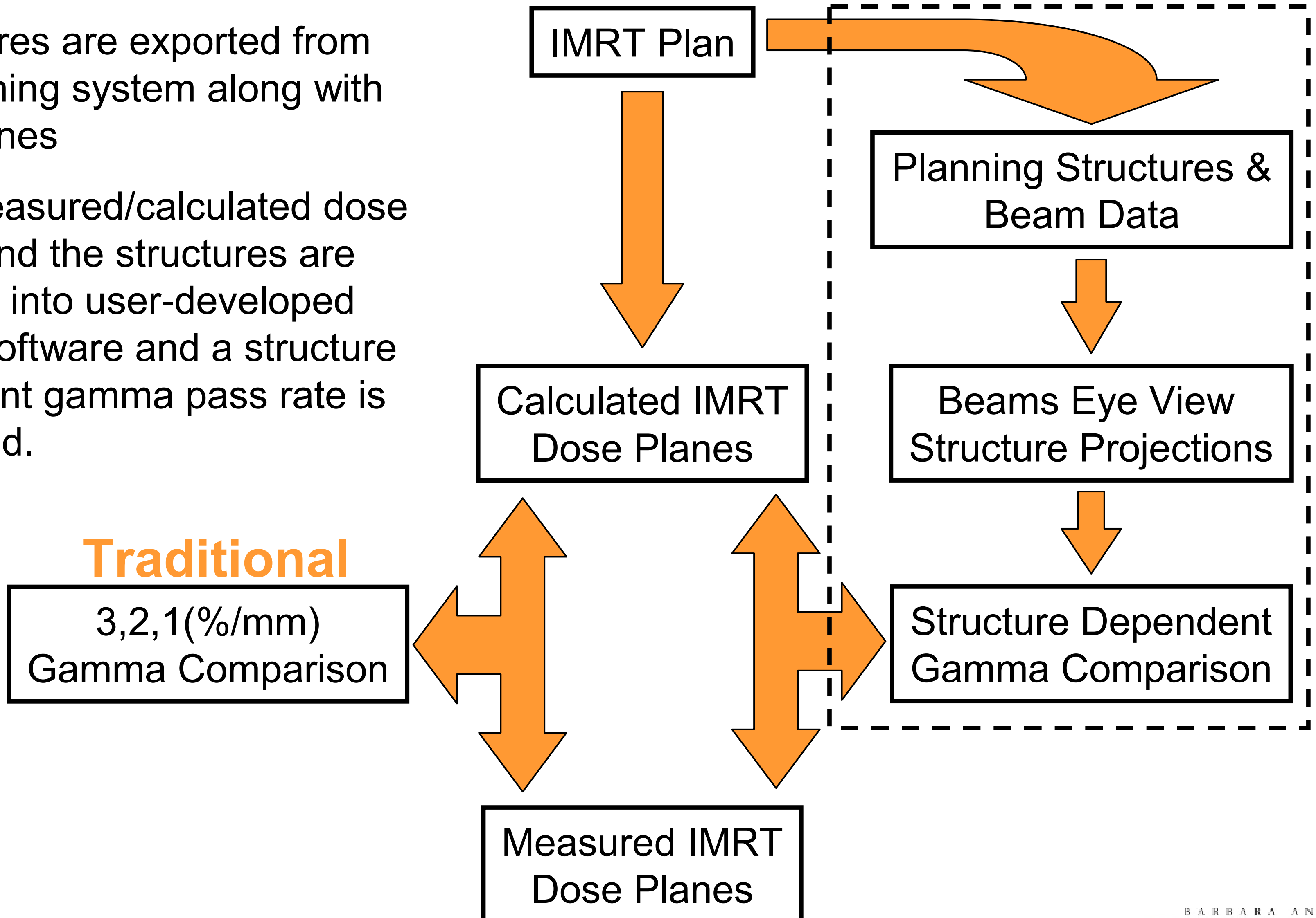
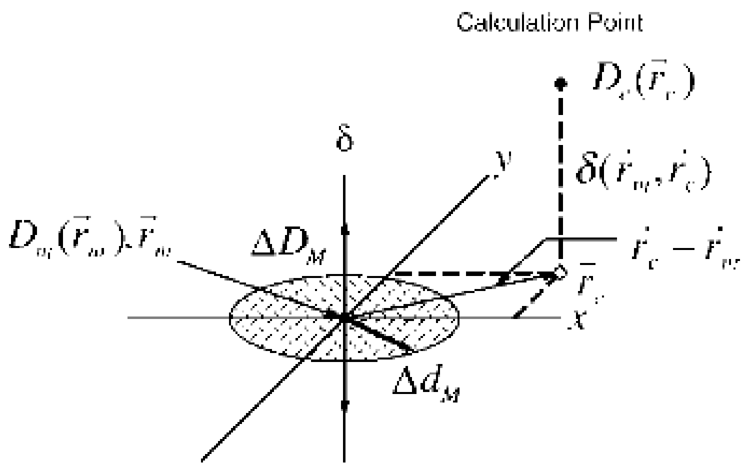
Structure Dependent Gamma Analysis

- Structures are exported from the planning system along with dose planes
- The measured/calculated dose planes and the structures are imported into user-developed Matlab software and a structure dependent gamma pass rate is calculated.



Passing Criteria in Gamma Calculations



$$\Gamma(\mathbf{r}_m, \mathbf{r}_c) = \sqrt{\frac{r^2(\mathbf{r}_m, \mathbf{r}_c)}{\Delta d_M^2} + \frac{\delta^2(\mathbf{r}_m, \mathbf{r}_c)}{\Delta D_M^2}}$$

$$\gamma(\mathbf{r}_m) = \min\{\Gamma(\mathbf{r}_m, \mathbf{r}_c)\} \forall \{\mathbf{r}_c\}$$

$$\gamma(\mathbf{r}_m) \leq 1, \text{ calculation passes,}$$

$$\gamma(\mathbf{r}_m) > 1, \text{ calculation fails.}$$

- Each measured point is compared to a small local subset of planned points.
- A gamma value is calculated for each comparison.
- The minimum gamma value at each measured point determines whether it passes or fails.
- **We vary the passing criteria in the gamma calculation.**

D. A. Low, W. B. Harms, S. Mutic, and J. A. Purdy, “A technique for the quantitative evaluation of dose distributions,” Med. Phys. 25 (5), 656-661 (1998).

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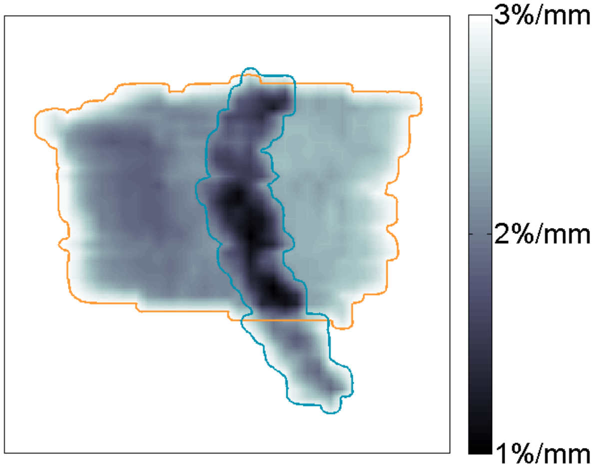
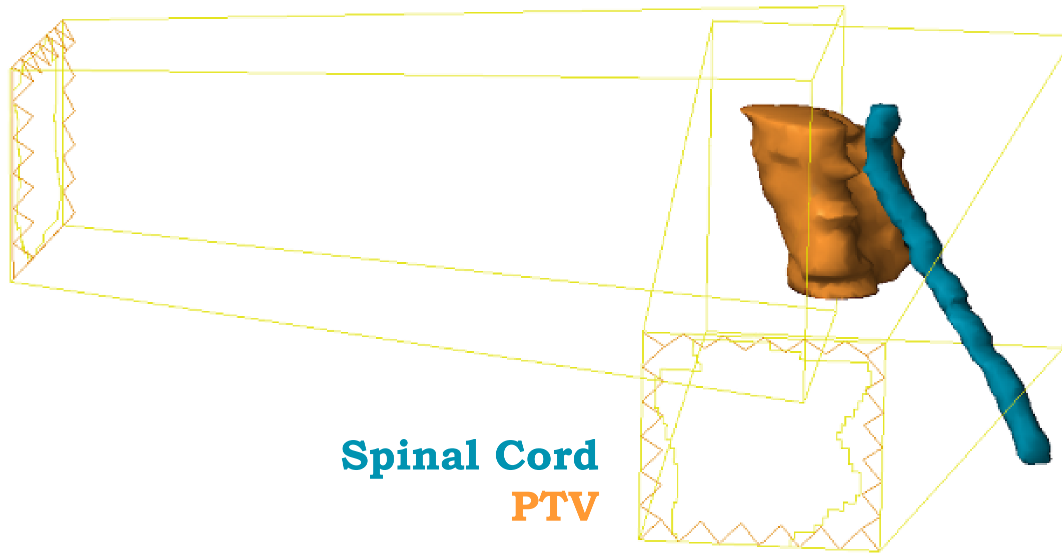
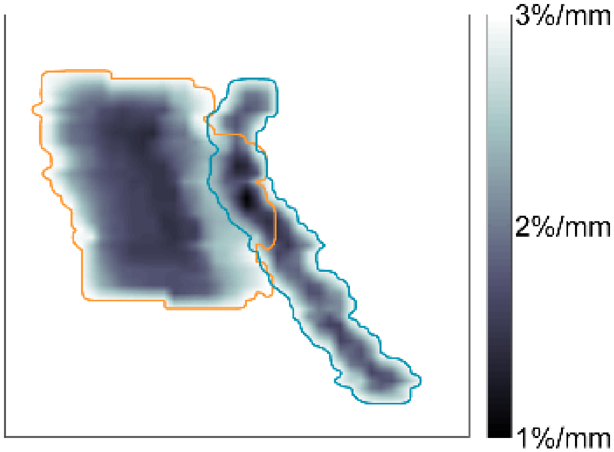
Structure Dependent Passing Criteria





- Each critical planning structure is projected from a beams-eye-view onto the IMRT QA dose plane.
- The passing criteria are varied in proportion to the thickness of the structures that the beam passed through.
- Emphasizes the importance of the portion of the beam that could have the largest effect on clinically relevant dose.



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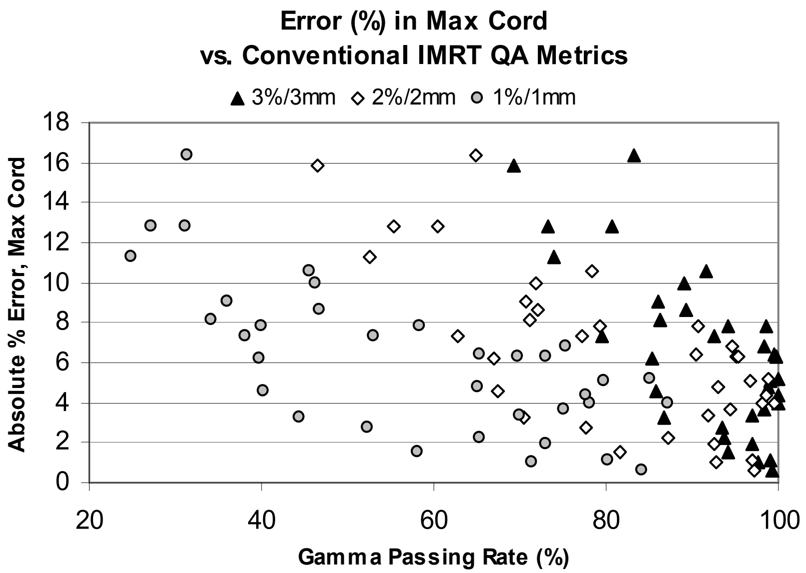
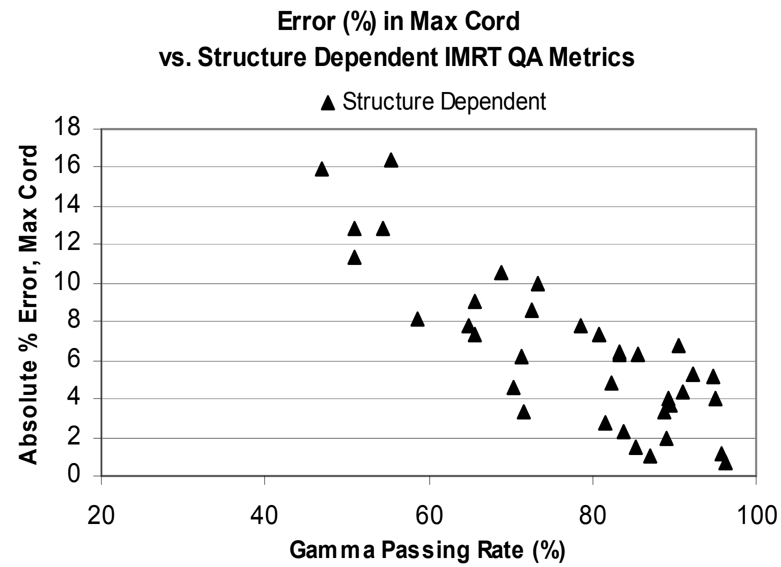
Max Cord Results

Traditional



	Spinal Cord Max error
IMRT QA Criteria	**Pearson r-value**
3%/3mm	-0.717
2%/2mm	-0.720
1%/1mm	-0.750

Structure Dependent



	Spinal Cord Max error
IMRT QA Criteria	**Pearson r-value**
Structure Dependent	**-0.831**

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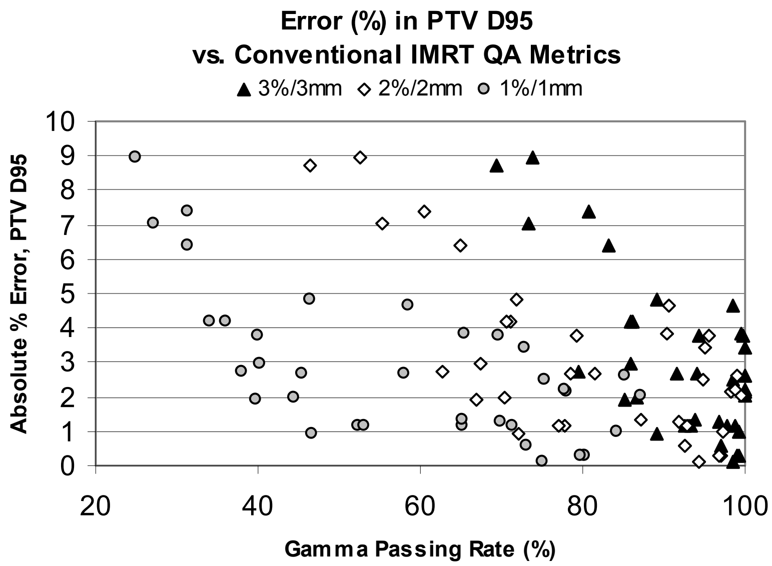
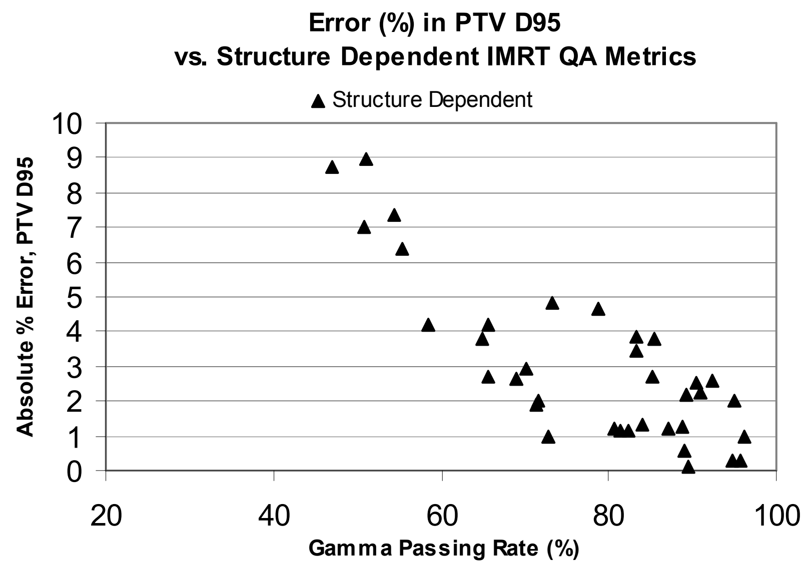
PTV D95 Results

Traditional



	PTV D95 error
IMRT QA Criteria	**Pearson r-value**
3%/3mm	-0.729
2%/2mm	-0.703
1%/1mm	-0.711

Structure Dependent



	PTV D95 error
IMRT QA Criteria	**Pearson r-value**
Structure Dependent	**-0.812**

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Conclusion

- Using structure dependent gamma criteria creates a stronger correlation between outcomes of IMRT QA and clinical dose deviations.

- The structure dependent gamma criteria results in increased QA emphasis in the clinically important areas of the fields.

Future Work

- This study was limited to head and neck IMRT cases. The same investigation needs to be applied to other treatment sites.

- The structure dependent IMRT QA needs to be tested for other combinations of treatment planning systems/QA procedures.

- This technique needs to be tested for other sources of error that could affect IMRT plans.

BARBARA ANN KARMANOS CANCER INSTITUTE
Wayne State University

Questions?

BARBARA ANN
KARMANOS
CANCER INSTITUTE
Wayne State University