SSIM Concept for IMRT QA Evaluation

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Back to the past (1984)-AAPM Report No. 13

CHAPTER 1

INTRODUCTION

Quality assurance in radiation therapy includes those procedures that ensure a consistent and safe fulfillment of the dose prescription to the target volume, with minimal dose to normal tissues and minimal exposure to personnel.

A comprehensive quality assurance program is necessary because of the importance of accuracy in dose delivery in radiation therapy. The dare-response curve in radiation therapy is quite steep in certain cases, and there is evidence that a 7-10% change in the dose to the target volume may result in a significant change in tuner control probability [53]. Similarly, such a dose change may also result in a sharp change in the incidence and severity of radiation induced morbidity.

Surveying the evidence on effective and excessive dose levels, Herring and Compton [38] concluded that the therapeutic system should be capable of delivering a dose to the tumor volume within 5% of the dose prescribed. Report 24 from the International Commission on Radiation Units and Measurements [53] lists several studier in support of this conclusion.

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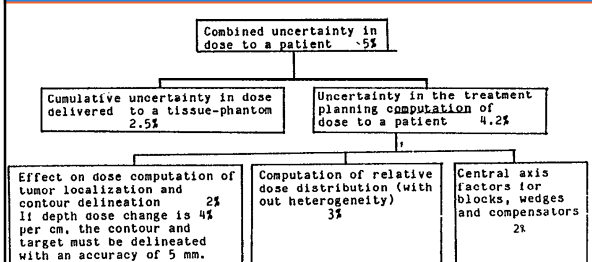

Figure 1a: Example of dosimetric uncertainties in the radiation therapy process. The uncertainties represent approximately the 95% confidence level.

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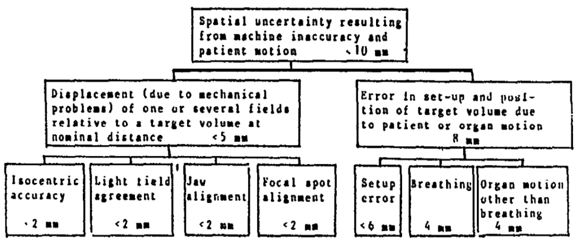


Figure lb: Example of spatial uncertainties (at the 95% confidence level) in the radiation therapy process.

Overall uncertainty in dose at a point

step	(2-σ) uncertainty (%)
dosimeter calibration	1.6
daily calibration	2.0
methods and parameters	3.0
effective depth	2.0
SSD	2.0
wedges	2.0
block trays	2.0
cumulative	5.6

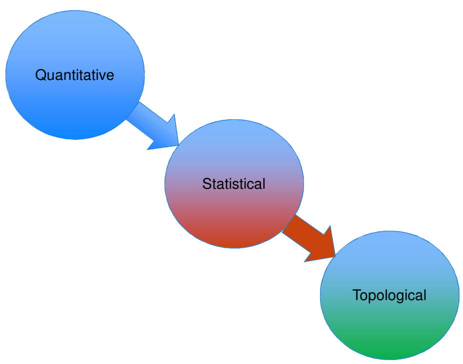
Overall uncertainty in dimension at a point

Step	(2-σ) uncertainty (mm)
Laser localization	2.0/1.5/1.0
ODI @ iso	2.0
Collimator size indicator	2.0/1.0
effective depth	2.0
Light/radiation field	2.0/1.0
Cross-hair centering	1.0
Couch position	2.0
Wedge placement	2.0
Compensator placement	1.0
Cumulative	5.0

Summary about QA tolerance

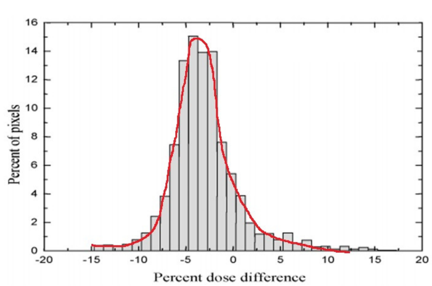
- Dose has uncertainties
- Distance has uncertainties
- Patient specific quality assurance (PSQA) will be affected by both dose and distance
- History data may or may not still be valid now
- How should we do PSQA?

Patient Specific Quality Assurance (PSQA)



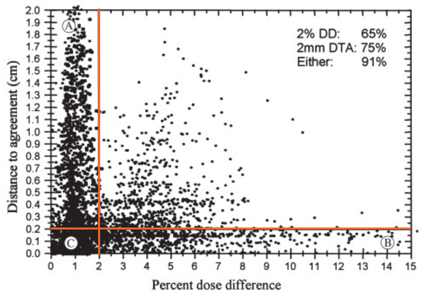
PSQA-Quantitative ways

- Dose Difference (DD)
  $DD=(D_{cal}-D_{mes})/D_{cal}\% \leq \pm 5\%$



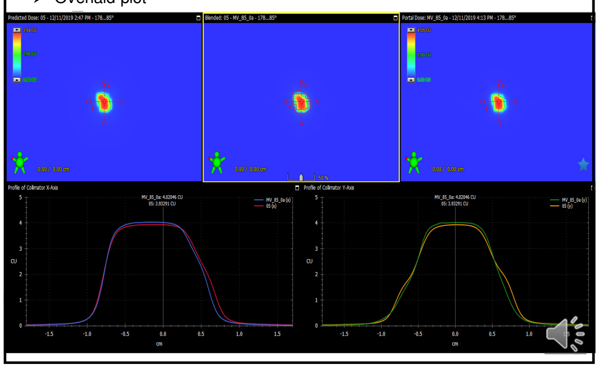
PSQA-Quantitative ways

- Distance To Agreement (DTA): considering high- and low-gradient regions each with a different acceptance criterion. Van Dyk et al. (1993)



PSQA-Quantitative ways

- Overlaid plot



PSQA-Quantitative ways

- DD or DTA or overlaid plot
  - **Designed during 3D CRT era**
  - **Only consider one aspect (dose or distance)**
  - **Depending on human eyes**
  - **Link to PTV or OAR is weak**
  - **1D or 2D QA**

PSQA-Statistical ways

- Gamma Index: Low et al. (1998)
  - TG 119 (2009): DTA= 3 mm, DD=3%, 90% passing with 10% threshold
  - TG 218 (2018): DTA= 2 mm, DD=3% ,95% passing with 10% threshold

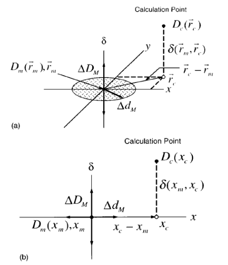


FIG. 1. Geometric representation of dose distribution evaluation criteria for the dose-difference and distance-to-agreement tests. (a) Two-dimensional representation. (b) One-dimensional representation.

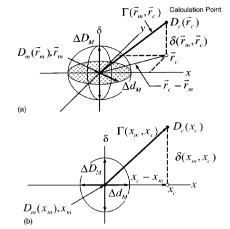


FIG. 2. Geometric representation of dose distribution evaluation criteria using the combined ellipsoidal dose-difference and distance-to-agreement tests. (a) Two-dimensional representation. (b) One-dimensional representation.

PSQA-Statistical ways

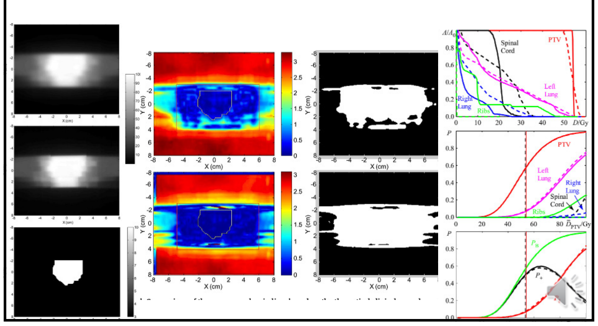
- Gamma Index issues
  - **Passing gamma dese not mean the plan is acceptable** (Kruse JJ. On the insensitivity of single field planar dosimetry to IMRT inaccuracies. Med Phys. 37(6), 2010.)
  - **No correlation with patient DVH** (Stasi M, Bresciani S, Miranti A, *et al.* Pretreatment patient-specific IMRT quality assurance: a correlation study between gamma index and patient clinical dose volume histogram. Med Phys. 39(2), 2012.)
  - **Cannot detect systematic errors** (Nelms BE, Chan MF, Jarry G, *et al.* Evaluating IMRT and VMAT dose accuracy: practical examples of failure to detect systematic errors when applying a commonly used metric and action levels. Med Phys. 40(11), 2013.)
  - **No link with biomathematical treatment outcome models** (Garcia-Romero A, Hernandez-Vitoria A, Millan-Cebrian E, *et al.* On the new metrics for IMRT QA verification. Med Phy. 43(11), 2016.)
  - **Cannot distinguish equipment differences**
  - **Do not distinguish shapes (PTV, OARs)**
  - **May not be suitable real time monitoring**

PSQA-Topological ways

Comput Methods Programs Biomed. 2014 Apr;114(1):60-9. doi: 10.1016/j.cmpb.2014.01.005. Epub 2014 Jan 15.

γ+ index: A new evaluation parameter for quantitative quality assurance.

Stathakis S[1], Mavroidis P[2], Shi C[3], Xu J[3], Kauweloa KI[3], Narayanasamy G[3], Papanikolaou N[3].



PSQA-Topological ways

- SSIM

600 IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 13, NO. 4, APRIL 2004

Image Quality Assessment: From Error Visibility to Structural Similarity

Zhou Wang, *Member, IEEE*, Alan Conrad Bovik, *Fellow, IEEE*, Hamid Rahim Sheikh, *Student Member, IEEE*, and Eero P. Simoncelli, *Senior Member, IEEE*

$$\mathrm{SSIM}(x,y) = f\left(l(x,y)^{\alpha}, c(x,y)^{\beta}, s(x,y)^{\gamma}\right)$$

$$l\,(x,y) = \frac{2u_x u_y + C_1}{u_x^2 + u_y^2 + C_1},\ C_1 = (K_1 L)^2,\ K_1 \ll 1$$

$$\mathrm{c}(x,y) = \frac{2\delta_x \delta_y + C_2}{\delta_x^2 + \delta_y^2 + C_2},\ C_2 = (K_2 L)^2,\ K_2 \ll 1$$

$$\mathrm{s}(x,y) = \frac{\delta_{xy} + C_3}{\delta_x \delta_y + C_3},\ C_3 = {}^{C_2}/_{2}$$

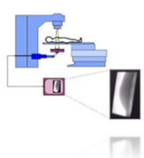
$\alpha=\beta=\gamma=1$, $K_1=0.01$, $K_2=0.03$, L=255

Implementation in RT

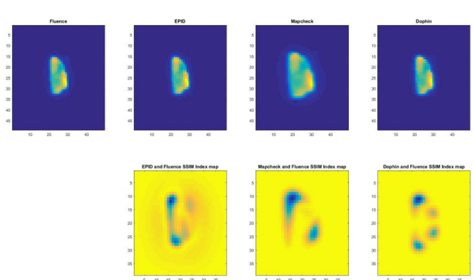
L=fluence map
C= SNR
S=fluence map shape

We have calculated fluence map
EPID
2D array, such as MapCHECK
2D array, such as Dophin

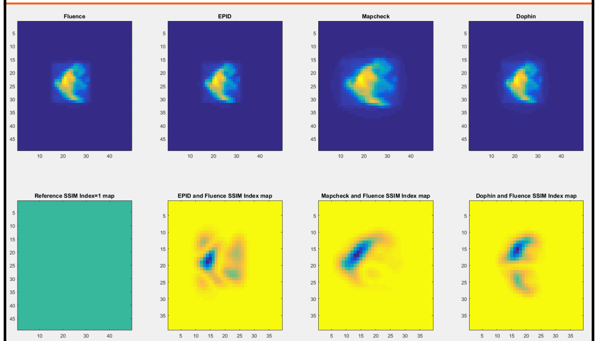
Which one is the best to measure calculated fluence map?



Implementation in RT-Lung1



Implementation in RT-Brain1



Summary of 6X Pre-clinical IMRT QA

Plan	Field 01	Field 02	Field 03	Field 04	Field 05	Field 06	Field 07	Dophin SSIM
Lung1	0.9976	0.9947	0.9938	0.9926	0.9922			
Lung2	0.9997	0.9999	0.9984	0.997	0.9978	0.9999	0.9971	
Brain1	0.9999	0.9998	0.9999	0.9994	0.9995	0.9991		
Brain2	1.0000	0.9999	1.0000	1.0000	1.0000	1.0000		
GI	0.9973	0.9997	0.9985	0.9988	0.9997	0.9991	0.9987	

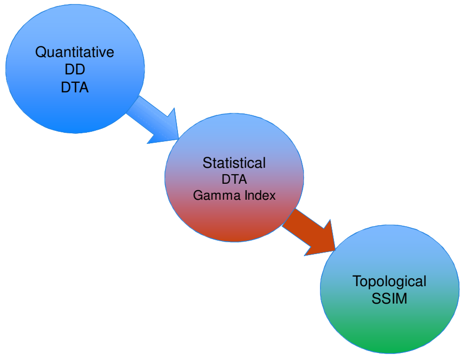
Plan	Field 01	Field 02	Field 03	Field 04	Field 05	Field 06	Field 07	Mapcheck SSIM
Lung1	0.9884	0.9854	0.9859	0.9831	0.9787			
Lung2	0.9983	0.9984	0.9951	0.9942	0.996	0.999	0.9935	
Brain1	0.9995	0.9993	0.9995	0.9987	0.9988	0.9976		
Brain2	0.9999	0.9995	0.9998	0.9998	0.9998	0.9998		
GI	0.9909	0.9978	0.9969	0.9979	0.9987	0.9979	0.9975	

Plan	Field 01	Field 02	Field 03	Field 04	Field 05	Field 06	Field 07	EPID SSIM
Lung1	1.000	1.000	1.000	1.000	1.000			
Lung2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Brain1	1.000	1.000	1.000	1.000	1.000	1.000		
Brain2	1.000	1.000	1.000	1.000	1.000	1.000		
GI	1.000	1.000	1.000	1.000	1.000	1.000	1.000	

Discussion

- Based on the data analysis, we found that EPID>Dophin>MapCHECK
- SSIM will only show the differences, but we do not have a tolerance for pass/fail yet
- Further investigation is needed to set up the tolerance.
- Or we may not need a tolerance? Deriving a "bottom reference" SSIM based on DVH and anything above it is acceptable?

Patient Specific Quality Assurance (PSQA)



Summary

- We have reviewed QA, PSQA methods and SSIM concept
- We have analyzed the factors affecting SSIM
- We have preliminary results using SSIM for RT

Thank You!