SSIM Concept for IMRT QA Evaluation

Chengyu Shi, Ph.D.

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 dose-response curve in radiation therapy is quite steep in certain cases, and there is evidence that a $\Delta_{\text{dose}}$ change in the dose to the target volume may result in a significant change in tumor control probability [5]. 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 systems should be capable of delivering a dose to the target volume within 5% of the dose prescribed. Report 24 from the International Commission on Radiation Units and Measurements [55] lists several studies in support of this conclusion.

Figure 1a: Example of dosimetric uncertainties in the radiation therapy process. The uncertainties represent approximately the 95% confidence level.
### Overall uncertainty in dose at a point

<table>
<thead>
<tr>
<th>Step</th>
<th>(2-σ) uncertainty (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>dosimeter calibration</td>
<td>1.6</td>
</tr>
<tr>
<td>daily calibration</td>
<td>2.0</td>
</tr>
<tr>
<td>methods and parameters</td>
<td>3.0</td>
</tr>
<tr>
<td>effective depth</td>
<td>2.0</td>
</tr>
<tr>
<td>SSD</td>
<td>2.0</td>
</tr>
<tr>
<td>wedges</td>
<td>2.0</td>
</tr>
<tr>
<td>block trays</td>
<td>2.0</td>
</tr>
<tr>
<td>cumulative</td>
<td>5.6</td>
</tr>
</tbody>
</table>

### Cumulative

- 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)**

- Quantitative
- Statistical
- Topological

**PSQA-Quantitative ways**

- Dose Difference (DD)
  \[ DD = \frac{(D_{\text{cal}} - D_{\text{meas}})}{D_{\text{cal}}} \% \leq \pm 5\% \]
PSQA-Quantitative ways

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

- Overlaid plot

- 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 issues
  - Passing gamma dose not mean the plan is acceptable (Kruse JJ. On the insensitivity of single field planar dosimetry to IMRT inaccuracies. Med Phys. 37(6), 2010.)
  - Cannot distinguish equipment differences
  - Do not distinguish shapes (PTV, OARs)
  - May not be suitable real time monitoring

PSQA-Statistical ways

- 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

PSQA-Topological ways

\[
\gamma^* \text{ index: A new evaluation parameter for quantitative quality assurance.}
\]

\[
\text{Graphical representation of } \gamma^* \text{ index}
\]
PSQA-Topological ways

- SSIM

Image Quality Assessment: From Error Visibility to Structural Similarity

$$SSIM(x, y) = \frac{1}{2^{\alpha+\beta+\gamma}} \cdot c(x, y)^\alpha \cdot s(x, y)^\beta \cdot r(x, y)^\gamma$$

$$c(x, y) = \frac{2\mu_x \mu_y + \sigma_x \sigma_y \cdot K}{\mu_x^2 + \mu_y^2 + \sigma_x^2 + \sigma_y^2 \cdot K}$$

$$s(x, y) = \frac{2\sigma_x \sigma_y + \delta_x \delta_y \cdot K}{\sigma_x^2 + \sigma_y^2 + \delta_x^2 + \delta_y^2 \cdot K}$$

$$r(x, y) = \frac{\delta_x \delta_y + \alpha \sigma_x \sigma_y}{\delta_x \delta_y + \beta \sigma_x \sigma_y}$$

Implementation in RT

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

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

Which one is the best to measure calculated fluence map?

Implementation in RT-Lung1
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)

Quantitative DD DTA
Statistical DTA Gamma Index
Topological SSIM

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!