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# Role of EPID in Linac Commission and the SSIM Concept for Evaluation

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*Memorial Sloan Kettering Cancer Center*
AAPM Annual Meeting 2019

## Disclosure

I owe to my colleagues for their excellent works on this talk…

Gary Lim
Ziad Saleh
Maria Chan
Michael Lovelock
Dosimetry Group
MP Computer Services
Treatment Planning Group
Margie Hunt
Joe Deasy

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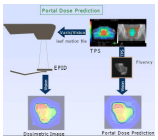
## This talk introduces you different EPID applications in the clinic



Conventional PD


SSIM Concept


MPC

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## Pre-clinical IMRT QA/MLC QA

- Part of commission tasks for two brand new TrueBeam machines
- Clinical plans were run on the machine to deliver fluence map on EPID at SDD 100 cm
- Gamma index was used for QA result analysis
- For portal dosimetry, used 3%Local/3mm and 10% threshold

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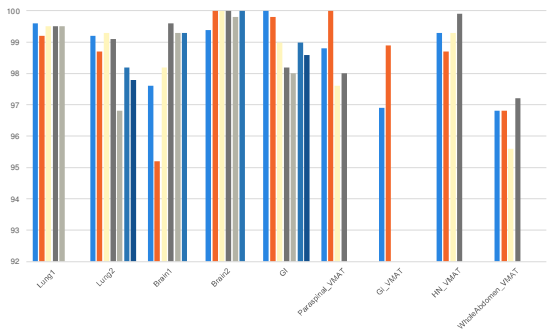
## Gamma Passing Rates for 6X

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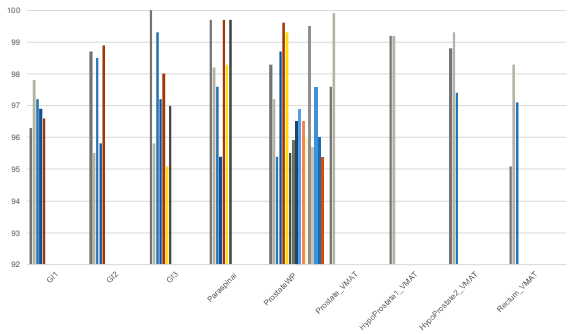
## Gamma Passing Rates for 15X

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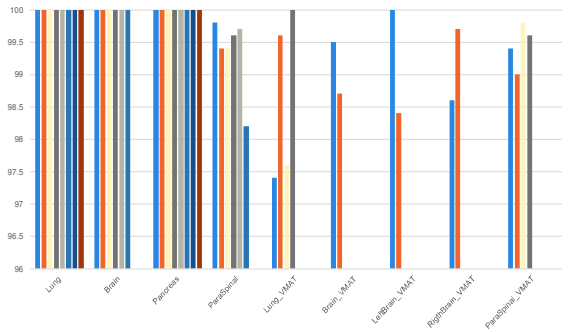
## Gamma Passing Rates for 6XFFF

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## Clinical Findings for Pre-IMRT QA

- EPID can be used for pre-clinical IMRT QA
- The gamma passing rate is depending on beam energy and plan complexity
- 3%Local/3mm with threshold 10% and 95% may be proper for absolute dose comparison
- Some IMRT fields failed for the gamma passing rates, therefore a customized calibration file may be needed.

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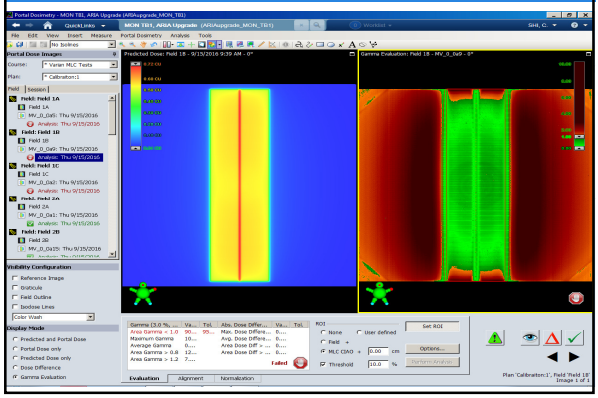
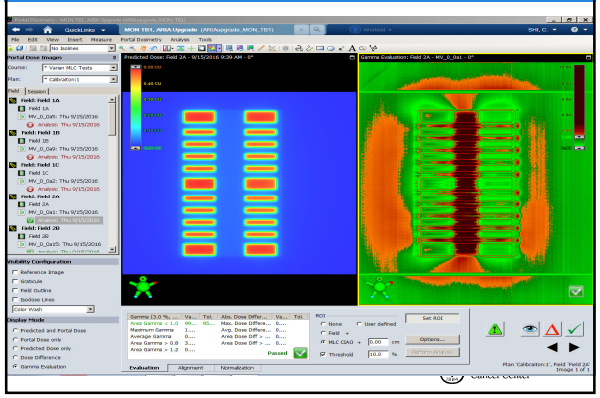
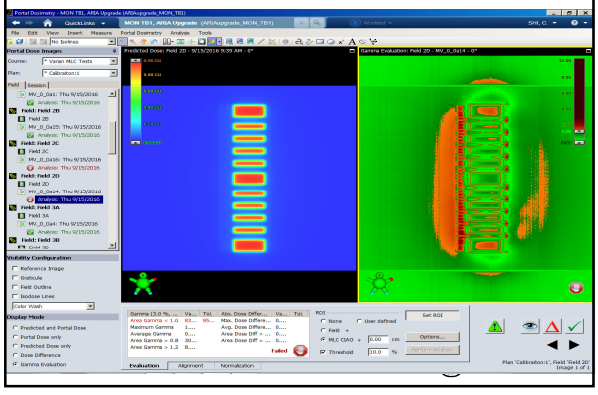
## Test1B-Fail



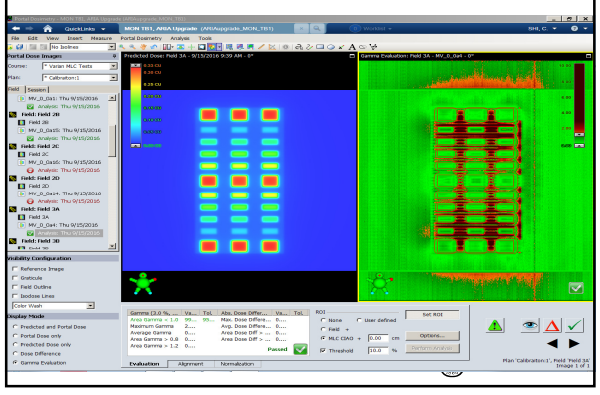
## Test2A-Pass



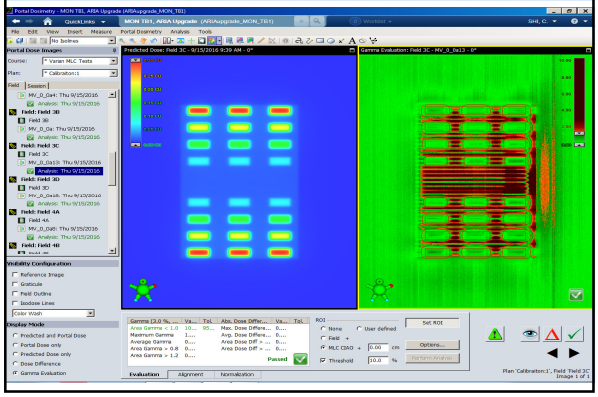
## Test2D-Fail



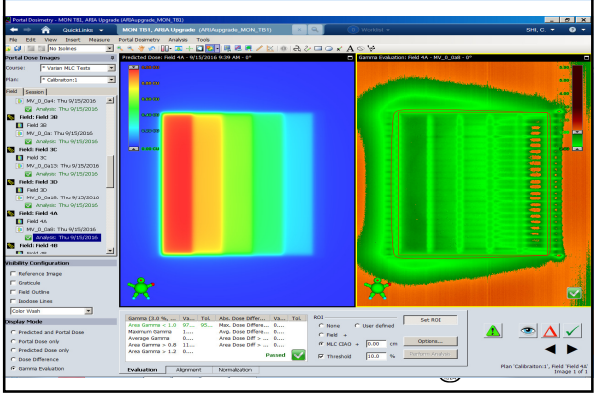
## Test3A-Pass



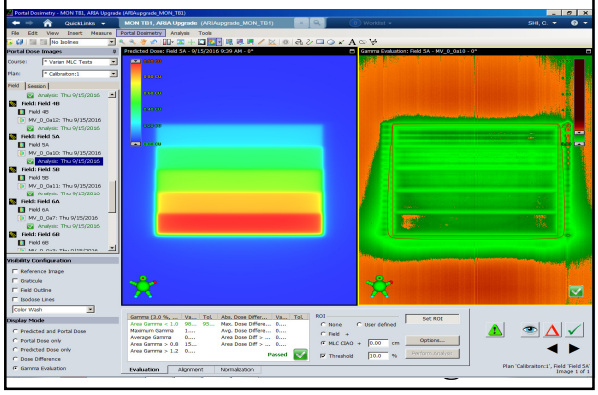
## Test3C-Pass



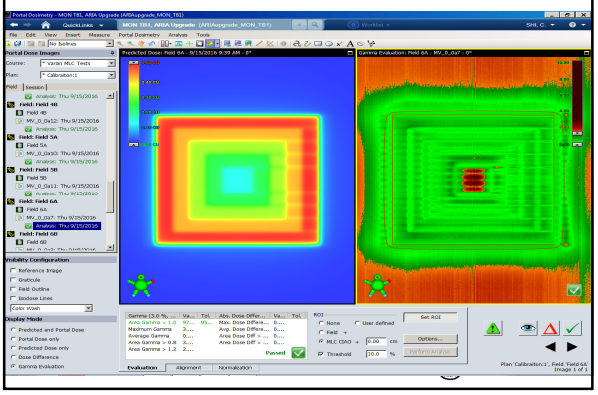
## Test4A-Pass



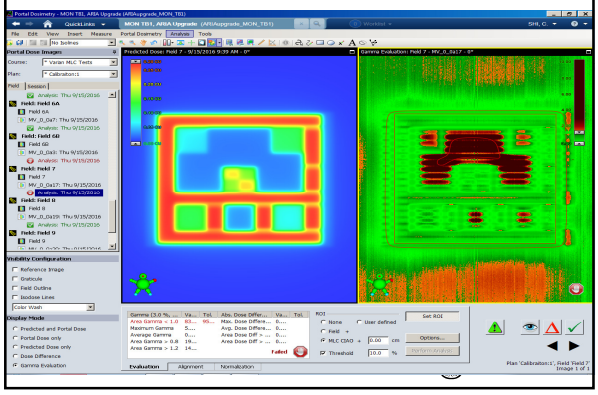
## Test5A-Pass



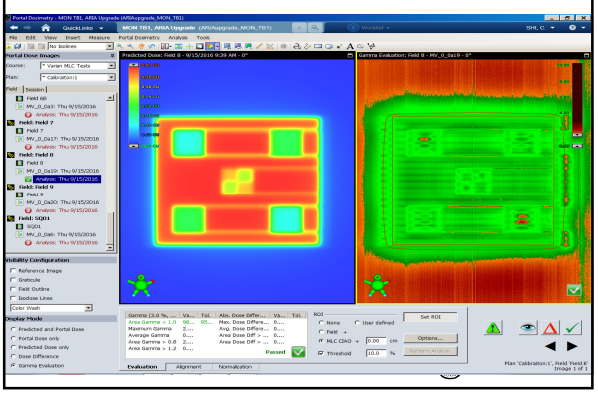
## Test6A-Pass



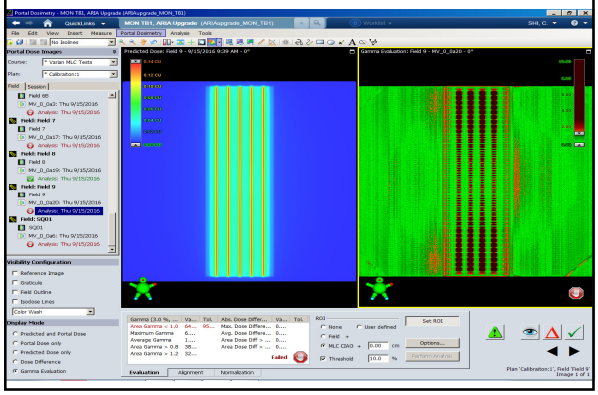
## Test7-Fail



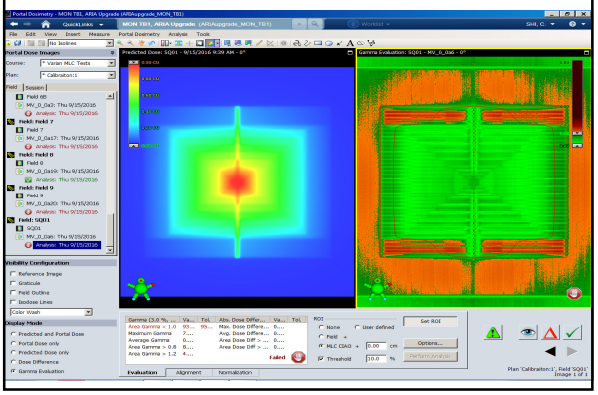
## Test8-Pass



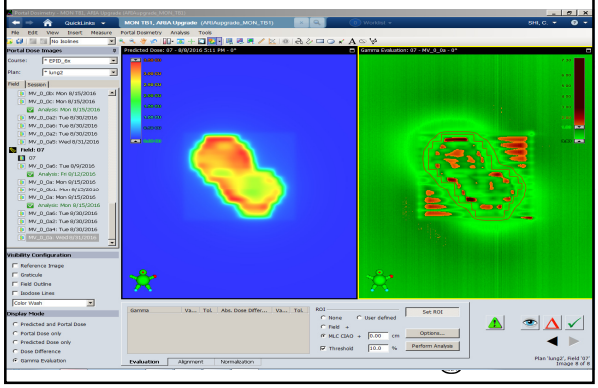
## Test9-Fail



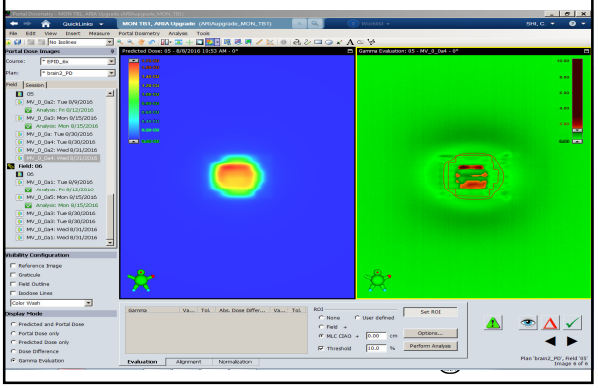
## Test Square Field-in-Field-Fail



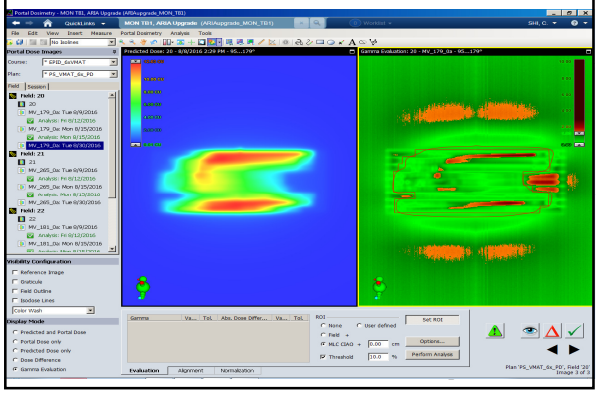
## Test 6X lung2



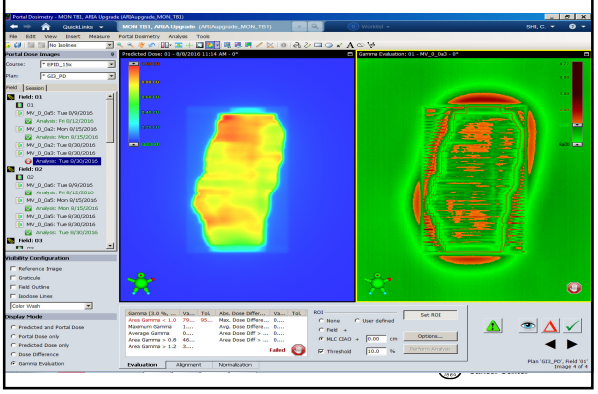
## Test 6X Brain 2



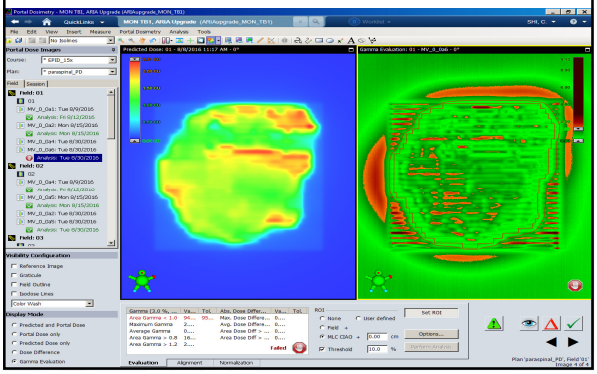
## Test 6X Pelvis VMAT



## Test 15X GI3



## Test 15X Paraspinal



## Summary and Observation

- The failure patterns are complex
- EPID itself may contribute to the failure also
- Large field is easy to fail due to scatter dose and MLC leakage during the transition, such as Tests 1 and 9
- Highly modulated field with low dose region is easy to fail, such as Test 7
- Small field is easy to fail also, such as 6X Brain 2
- Using 3%Local/3mm , TH=10%, and 95% passing rate may not fit all cases
- A customized calibration file is necessary for special cases

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## SSIM or Gamma Index?

- What is SSIM?
- Factors affecting SSIM calculation
- Implementation in RT
- Summary

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## What is 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*

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

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

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

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

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

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## SSIM Properties

$\mathrm{SSIM}(x,y) = \mathrm{SSIM}(y,x)$
$\mathrm{SSIM}(x,y) \leq 1$
$\mathrm{SSIM}(x,y) = 1$, if and only if x=y

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## Diagram of SSIM Measurement System

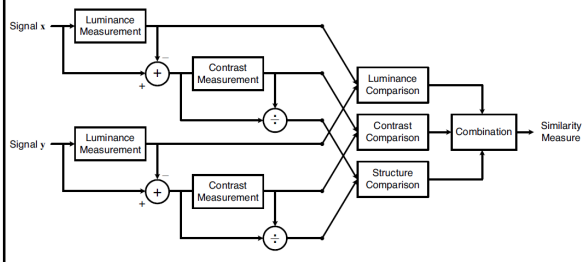


Fig. 3. Diagram of the structural similarity (SSIM) measurement system.

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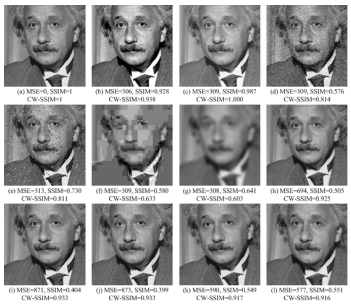
## Example from Wang



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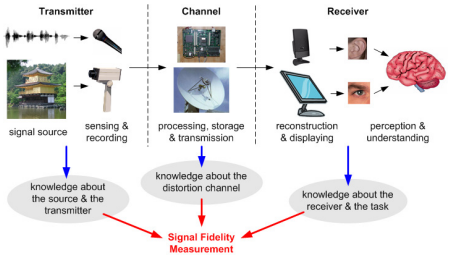
## Example from Wang

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## Factors Affecting SSIM Calculation

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

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

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

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

In Wang's paper: α=β=γ=1, $K_1$=0.01, $K_2$=0.03, L=255

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## Factors Affecting SSIM Calculation

TECHNICAL REPORT TR-CS 2008-2, SEPTEMBER 2008

**A Formal Assessment of the Structural Similarity Index**

Richard Dosselmann and Xue Dong Yang

$R^2$ CORRELATION COEFFICIENTS OF MSE VS. SSIM

| Test Image | Luminance Shift | Contrast Adjustment | Random Noise | Gaussian Noise | Averaging Blur | Gaussian Blur | JPEG Compression | AVERAGE |
|---|---|---|---|---|---|---|---|---|
| Barbara | 1.0000 | 0.9847 | 0.9957 | 0.9975 | 0.9780 | 0.9906 | 0.9957 | 0.9917 |
| boat | 1.0000 | 0.9939 | 0.9910 | 0.9926 | 0.9820 | 0.9808 | 0.9956 | 0.9908 |
| cameraman | 0.9992 | 0.9710 | 0.9922 | 0.9832 | 0.9812 | 0.9757 | 0.9792 | 0.9831 |
| couple | 0.9999 | 0.9875 | 0.9960 | 0.9978 | 0.9362 | 0.9744 | 0.9973 | 0.9842 |
| Einstein | 1.0000 | 0.9487 | 0.9907 | 0.9952 | 0.9754 | 0.9798 | 0.9959 | 0.9837 |
| Goldhill | 1.0000 | 0.9727 | 0.9971 | 0.9977 | 0.9657 | 0.9645 | 0.9965 | 0.9849 |
| house | 1.0000 | 0.9562 | 0.9930 | 0.9816 | 0.9633 | 0.9846 | 0.9862 | 0.9807 |
| lake | 0.9985 | 0.9808 | 0.9945 | 0.9951 | 0.9549 | 0.9821 | 0.9991 | 0.9864 |
| Lena | 1.0000 | 0.9838 | 0.9935 | 0.9924 | 0.9722 | 0.9932 | 0.9959 | 0.9901 |
| man | 1.0000 | 0.9903 | 0.9948 | 0.9973 | 0.9414 | 0.9813 | 0.9966 | 0.9860 |
| mandrill | 1.0000 | 0.9897 | 0.9963 | 0.9994 | 0.9322 | 0.9506 | 0.9950 | 0.9805 |
| MIT | 0.9999 | 0.9499 | 0.9879 | 0.9926 | 0.9698 | 0.9921 | 0.9943 | 0.9838 |
| peppers | 1.0000 | 0.9856 | 0.9892 | 0.9925 | 0.9738 | 0.9912 | 0.9955 | 0.9897 |
| Tiffany | 1.0000 | 0.9987 | 0.9980 | 0.9947 | 0.9798 | 0.9921 | 0.9978 | 0.9944 |
| woman | 1.0000 | 0.9838 | 0.9903 | 0.9872 | 0.9897 | 0.9836 | 0.9994 | 0.9906 |
| AVERAGE | 0.9998 | 0.9785 | 0.9933 | 0.9931 | 0.9664 | 0.9811 | 0.9947 | 0.9867 |

## Implementation in RT

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

We have calculated fluence maps:
- EPID
- MapCHECK™
- Dophin™

Which one is the best to measure calculated fluence map?

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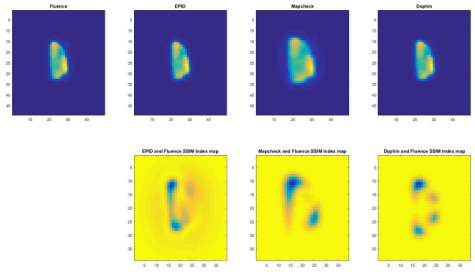
## Implementation in RT-Lung1



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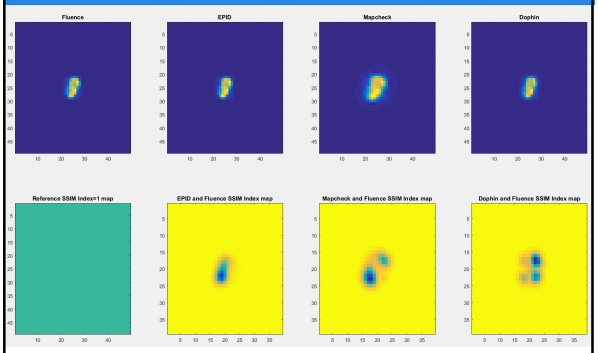
## Implementation in RT-Lung2

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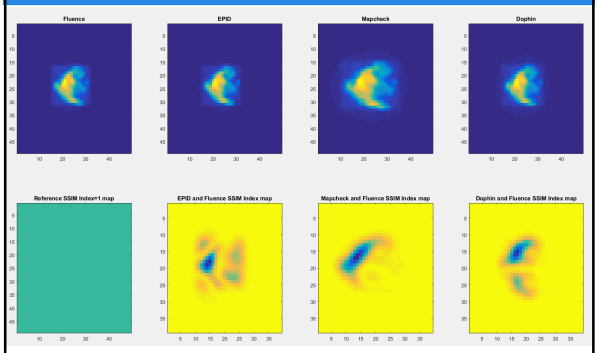
## Implementation in RT-Brain1

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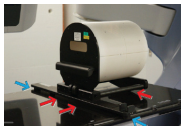
## Machine Performance Check (MPC)

- MPC is a self check process that Varian provides for all TrueBeam
- Capable of Dosimetric and Geometric QA testing
  - We are only interested in the geometric tests, the Sun Nuclear Daily QA3 device is used for dosimetric QA
- Run time for the mechanical tests is ~ 7 min
- Several hundred measurements are made
  - Individual static leaf positions
  - Positions of BBs implanted in the Isocal phantom
- Approx 190 test results are presented
- The tolerances are :
  - Tight
  - Set by Varian,
  - We cannot alter them
  - The result of each test either Pass Warning Fail



Courtesy Michael Lovelock, Ph.D.

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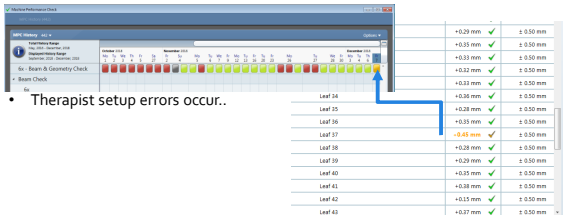
## Pass or Fail? That is a question

Therapist sees a single result, which is the worst case – if one tests fails, the therapist will see an overall Fail



- Therapist setup errors occur..

Courtesy Michael Lovelock, Ph.D.

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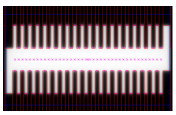
## Tasks We Can Test

- Isocenter:
  - Size, Panel positioning errors
- Collimation
  - Rotation
  - Jaws
  - MLC
- Gantry
  - Rotation, absolute and relative
- 6D Couch tests
  - X, Y, Z translations
  - Pitch roll yaw
  - Induced shift at isocenter



Courtesy Michael Lovelock, Ph.D.

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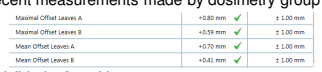
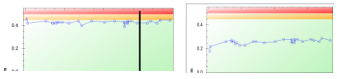
## Collimation

- In the standard tests suit, MV panel is at 50 cm from iso, the outer 20 leaves are not tested.
- (All leaves can be tested using additional tools from the tool box)
- Numbers from the MLC Reproducibility Summary are consistent with recent measurements made by dosimetry group



- Each visible leaf position is measured and can be trended
- Leaves A37, A38 Room 442



Courtesy Michael Lovelock, Ph.D.

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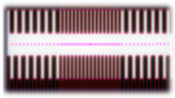
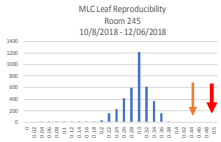
## MLC Reproducibility

- Test was added in Version 2.7
- Leaves set in a static comb pattern twice, the leaves approach the set position from different directions.
- The absolute difference in measured position when leaves approach set position from different directions (backlash) is reported






Courtesy Michael Lovelock, Ph.D.

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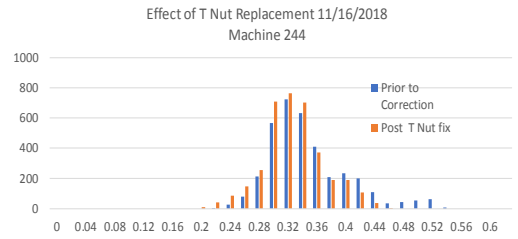
## Effect of T Nut Replacement




Courtesy Michael Lovelock, Ph.D.

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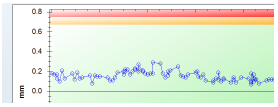
## Couch Pitch and Roll Tests

- Because MSK treatment workflows include, under specific conditions 6D shift then treat, the Chief therapist required a daily check of the 6D couch pitch and roll function
- MPC met this requirement and was introduced as a daily test for the therapists to run, at least on TBs with 6D couches
- As a result, MPC was introduced to routine daily use ~ 2 years ago
- No couch test has failed

Pitch and Roll induced shifts at isocenter




Courtesy Michael Lovelock, Ph.D.

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## Summary

EPID can play more roles in clinic

Concerns still exist for certain tests accuracy

SSIM can be a better way to evaluate the test results

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