# MEASUREMENT METHODS FOR IMRT QA

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## Outline

- Describe three common methods of IMRT QA measurements
- Describe the pros and cons of each
- Compare results between methods
- Review literature on method results

## Three Most Common Measurement Methods

1. Beam-by-Beam (BbB) - perpendicular to chamber or diode array or EPID
2. Composite (summation) BbB (CBbB) - perpendicular to chamber or diode array or EPID
3. True composite - (all beams at actual planned positions) film + chamber or detector array in phantom

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4. Ion chamber only in true composite geometry

## Single Ion Chamber Dose Alone Insufficient
### (True Composite Geometry)

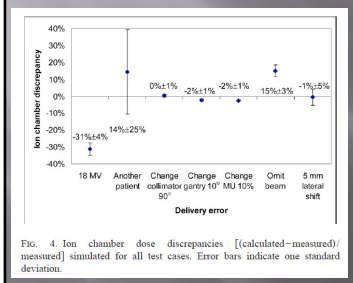



FIG. 4. Ion chamber dose discrepancies [(calculated−measured)/measured] simulated for all test cases. Error bars indicate one standard deviation.

Overall, only 54% of these delivery errors would be detected if an ion chamber measurement were performed using a 3% clinical tolerance level and 2D measurements were not performed.

**Childress, Med. Phys. 32 (1), 2005**

## Survey Performed on Methods Used

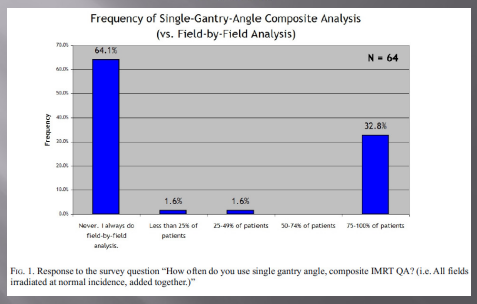
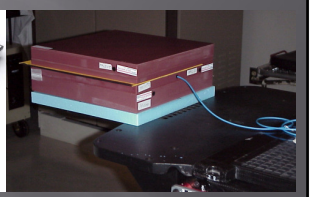



FIG. 1. Response to the survey question "How often do you use single gantry angle, composite IMRT QA? (i.e. All fields irradiated at normal incidence, added together.)"

Nelms, JACMP 8, 2007

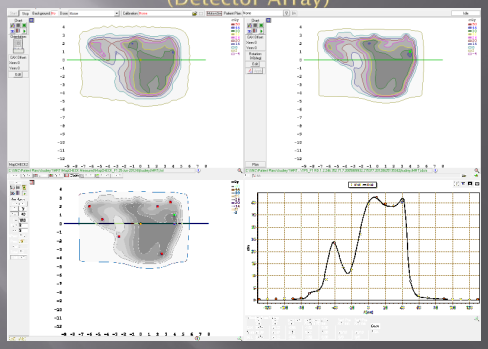
## Tools of the Trade



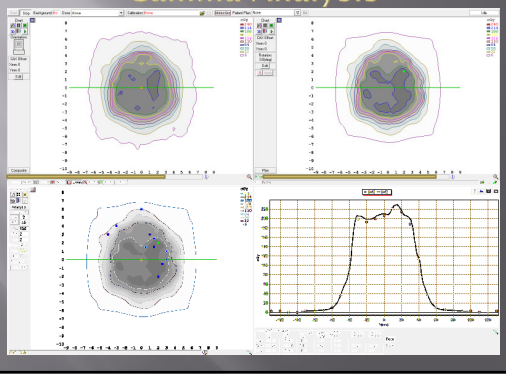
**Array: BbB or CBbB Or EPID**

**Film+Chamber: True Composite**

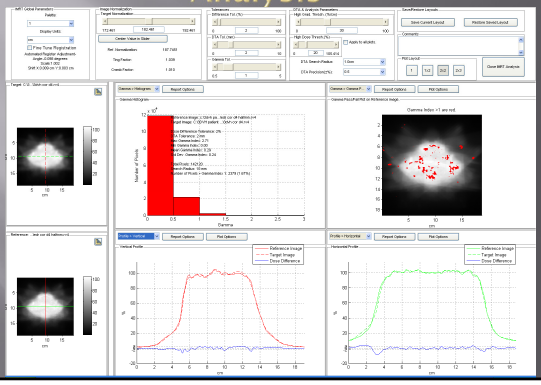
## Beam-by-Beam Gamma Analysis
(Detector Array)



## Composite Beam-by-Beam Gamma Analysis



## True Composite Gamma Analysis



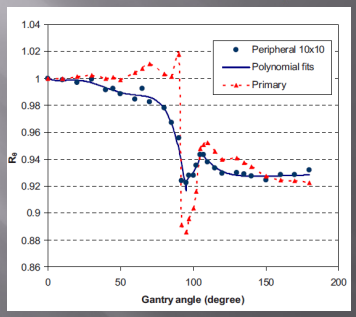
## Pros

- BbB and CBbB – Every part of every field is sampled, fast acquisition.
- CBbB – only one dose image to analyze. More uniform dose for analysis than BbB.
- True composite-Actual dose summation in a 2D slice of the 3D dose, couch, gantry errors included. Only one dose image to analyze.

## Cons

- BbB, CBbB – no sense of 3D summation. Can't know significance of regional errors in each beam.
- BbB - can get any Gamma result you want for relative dose mode by normalizing to a different place.
- CBbB – errors from each field may cancel on summation.
- True composite – more time consuming if film used. Does not sample every part of each beam. If an Array is to be used, less accurate for nearly lateral beams.

## Angular dependence of MatriXX chamber Array




Han, Med. Phys. 37, 2010

## BbB Gamma Results Don't Correlate to 3D Dose

- 3 plans, an acceptable version (all IC doses within 4% of TPS) and an unacceptable version.
- 8-18 ion chamber measurements in high dose low gradient and critical structure locations for true composite IMRT plans compared to EPID or Matrix beam-by-beam Gamma passing rates.

Kruse, Med. Phys. 37, 2010

## BbB Gamma Passing Rate Did Not Identify An Unacceptable Plan

| | Average gamma passing percentage: MATRIXX analysis | | | |
|---|---|---|---|---|
| | 2% dose/2 mm DTA | | 3% dose/3 mm DTA | |
| | Acceptable plan | Unacceptable plan | Acceptable plan | Unacceptable plan |
| Patient 1 | 94.9 (3.8) | 98.3 (1.1) | 99.2 (0.8) | 99.9 (0.2) |
| Patient 2 | 92.4 (4.5) | 86.8 (7.0) | 97.6 (3.2) | 96.9 (3.2) |
| Patient 3 | 92.8 (4.2) | 88.0 (6.1) | 99.5 (0.8) | 99.3 (0.7) |

Kruse, Med. Phys. 37, 2010

## Reconstruction of Patient 3D Dose from Simulated BbB Measurements

- Compared simulated BbB measurements with induced errors to calculated 3D doses in CTV and various organs at risk.
- Weak to moderate correlations between Gamma metric and DVH difference-based metrics
- Large rate of false negatives (you think the plan is ok but it is not).
- **The larger clinical errors happen for higher IMRT QA Gamma passing rates.**

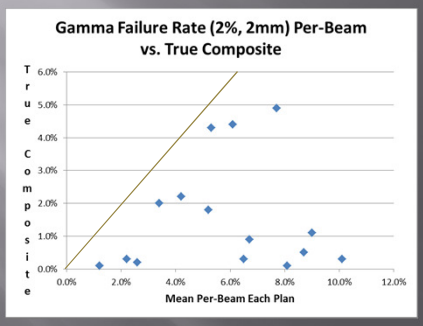
Nelms, et al. MedPhys 2011

## Are the Results of the Methods Comparable?

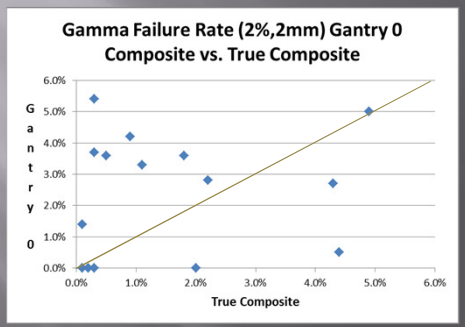
Intercomparison of
Gamma Passing Rates for all 3 Methods

- 15 IMRT patient cases
- True Composite (film) vs. Mean BbB
- True Composite (film) vs. CBbB
- 2%,2mm tolerance, 20% dose threshold, relative dose mode

## No Correlation– BbB vs. True Composite




## No Correlation– CBbB vs. True Composite



## True Composite vs. BbB (TG119)

TABLE XI. Composite film: Percentage of points passing gamma criteria of 3%/3 mm, averaged over the institutions, with associated confidence limits.

| Test | Location | Mean | Standard deviation ($\sigma$) | Maximum | Minimum | Number of submissions |
|---|---|---|---|---|---|---|
| Multitarget | Isocenter | 99.1 | 0.9 | 100 | 97.5 | 8 |
| Prostate | Isocenter | 98.0 | 2.24 | 99.8 | 94.2 | 7 |
| | 2.5 cm posterior | 93.2 | 7.6 | 99.9 | 85 | 3 |
| Head and neck | Isocenter | 96.2 | 3.0 | 100 | 92.4 | 8 |
| | 4 cm posterior | 97.5 | 1.5 | 98.9 | 95.6 | 4 |
| CShape (easier) | Isocenter | 97.6 | 3.9 | 100 | 88.9 | 7 |
| | 2.5 cm anterior to isocenter | 97.5 | 5.0 | 99.6 | 87.9 | 5 |
| CShape (harder) | Isocenter | 94.4 | 6.0 | 99.4 | 86.2 | 5 |
| | 2.5 cm anterior to isocenter | 95.0 | 7.2 | 99.9 | 81.3 | 5 |
| Overall combined | | 96.3 | 4.4 | | | |
| Confidence limit=(100−mean)+1.96$\sigma$ | | | | 12.4 (i.e., 87.6% passing) | | |

TABLE XIII. Per-field measurements: Average percentage of points passing the gamma criteria of 3%/3 mm, averaged over the institutions, with associated confidence limits.

| Test | Mean | Standard deviation ($\sigma$) | Maximum | Minimum |
|---|---|---|---|---|
| Multitarget | 97.8 | 3.5 | 99.8 | 90.8 |
| Prostate | 98.6 | 2.4 | 100 | 93.3 |
| Head and neck | 98.1 | 2.0 | 100 | 94.2 |
| CShape (easier) | 97.4 | 2.8 | 99.8 | 93.0 |
| CShape (harder) | 97.5 | 2.6 | 99.9 | 94.0 |
| Overall combined | 97.9 | 2.5 | | |
| Confidence limit=(100−mean)+1.96$\sigma$ | | 7.0 (i.e., 93.0% passing) | | |

TG 119: Med. Phys. 36, 2009

## Which Method is Best?

- Will one method detect failing plans better than another? BbB and TC better than CBbB
- Are results from one method comparable to the other method? Generally No
- If the Gamma metric passes, can relatively small regions with errors be related to the dose impact in the patient? TC

## Conclusions

- Each has its own pros and cons with variable ability to identify a delivery-to-TPS mismatch.
- One can not compare the results from one IMRT QA method to another
- True composite provides at least a 2D slice out of a 3D dose distribution, CBbB risks masking errors
- None of the methods discussed tells us the error in delivery of the 3D dose to the patient's PTV or critical organs.