Slide 1

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Moving from measurement based pre-treatment QA to trajectory file based QA

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Slide 2

Disclosure

- No conflict of interest to disclose

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Slide 3

Measurement Based Pretreatment PSQA

- 1D Detector
  - Ion chamber
  - OSL
- 2D Detector
  - 2D detector array
  - Film
  - EPID
- 3D Detector
  - Gel dosimeter
- Labor Intensive

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Slide 4

Trajectory Log Files

- Snapshots of the state of machine during delivery
  - Recorded by machine via internal sensors
  - Recorded by third party software
- Sampling frequency: from 20 ms to 250 ms
- File location varies
- Parameters of delivery
  - MU
  - Energy
  - Gantry angles
  - MLC position
  - Jaw position

Vendor	Varian		Elekta	
Type	DynaLog	Trajectory log	TRF	iCom
Machine Type	Clinac	TrueBeam	All	All
Sampling Time (ms)	50.0	20.0	25.0	250.0
Log file location	Local	Network	Local network	Local network
Time Stamp	Yes	Yes	Yes	Yes
MRN	Yes	Yes	No	Yes
Plan ID	Yes	Yes	Yes	Yes
Beam Name	Yes	Yes	Yes	Yes
MU	Yes	Yes	Yes	Yes
Dose Rate	Yes	Yes	Yes	Yes
Energy	Yes	Yes	Yes	Yes
MLC	Yes	Yes	Yes	Yes
Jaws	Yes	Yes	Yes	Yes
Gantry	Yes	Yes	Yes	Yes
Couch Position	Yes	Yes	Yes	Yes
Format Available	Yes	Yes	No	Yes

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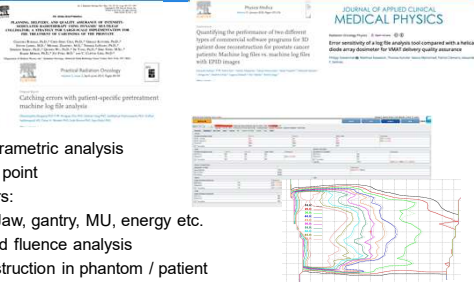
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Slide 5

Analysis

- Tools
  - In-house
  - Commercial
- Type of analysis
  - Automatic parametric analysis
    - By control point
    - Parameters:
      - MLC, Jaw, gantry, MU, energy etc.
  - Reconstructed fluence analysis
  - Dose Reconstruction in phantom / patient

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Slide 6

Varian nightly log analysis (MSKCC)

Dynalog Clinac's → Copy at 10pm → Logs on Network Drive → Analysis 12am-6am

Trajectory log TB's

ARIA

Analysis 12am-6am ↔ Database inquiry ↔ Cyclic redundancy check

Email notification | Output log | Clean logs

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Slide 7
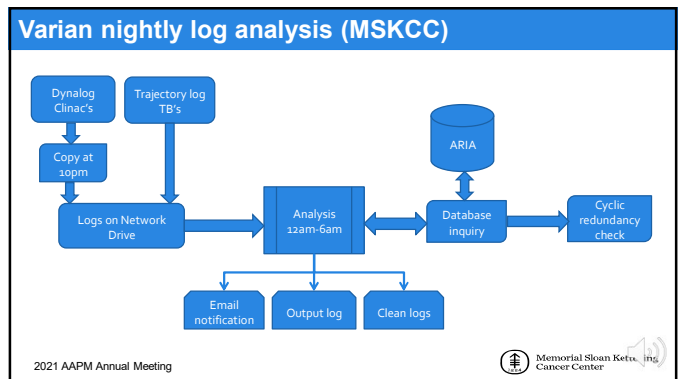
Example of a log file analysis

```
Campus: Main
Room Name: 442
MRN: 12345678
Patient Name: Test
Plan Name: 7_C7_T1_QQ
It is VMAT plan
BeamNumber in RTPlan: 1
BeamName in RTPlan: 01, BeamName in Log: 01
BeamDescription: 08VMAT
MU Planned in Log: 409, Delivered last MU: 408.9995, MU in RTPlan: 409
Trajectory .bin file Date/Time: 20130724182945
Trajectory .txt file Date/Time: 20130724182945
RTPLAN folder: \\sraospins\release\Data\3dtpDicom\12345678\7_C7_T1_QQ\RTPLAN.DCM
Carriage/Leaf #: A/29 -> Percent difference for this leaf(%): 15.1
Carriage/Leaf #: A/30 -> Percent difference for this leaf(%): 16.6
Carriage/Leaf #: B/27 -> Percent difference for this leaf(%): 17.7
Carriage/Leaf #: B/29 -> Percent difference for this leaf(%): 22.1
Carriage/Leaf #: B/32 -> Percent difference for this leaf(%): 19.7
Jaw positions no error
Gantry Angle no error
Coll. Rtn. no error
Planned MU is within tolerance
Delivered last MU is within tolerance
================
```

MLC deviation > 0.5 mm for more than 15% of the total beam-on time

Courtesy of Pengpeng Zhang

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Slide 8

MLC Error Dosimetric Impacts

Plan	Lung		Pancreas		Paraspinal	
	Avg dose difference	Gamma (1%/1mm)	Avg dose difference	Gamma (1%/1mm)	Avg dose difference	Gamma (1%/1mm)
0.5 mm			0.1%	100%	0.1%	99.4%
1.0 mm	0.1%	100%	0.1%	99.8%	0.3%	96.2%
1.5 mm	0.2%	99.5%	0.2%	97.1%	0.3%	94.1%
2.0 mm	0.3%	98.8%	0.3%	94.4%	0.5%	92.2%

Courtesy of Pengpeng Zhang

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Slide 9

Fluence and Dose Reconstruction

comparison : γ 2D (3.0% / 2.0mm / Cutoff < 5% /Local > 67% / γ% : 100.0%)

LinacView (Standard Imaging, Middleton, WI)

γ analysis between a machine log file and the corresponding plan using fluence comparison

Tyagi N, Yang K, Yan D. Comparing measurement-derived (3DVH) and machine log file-derived dose reconstruction methods for VMAT QA in patient geometries. J Appl Clin Med Phys. 2014 Jul 8;15(4):4645.

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Online Adaptive RT: 1.5T MR Linac online QA

Lim SB et al., An Investigation of using Logfile Analysis for Automated Patient Specific Quality Assurance in MRgRT, 2021 (Under Review)

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Slide 11

Predictive model for MLC failure

$R^2 = 0.86$

N = 142

Wu, B., Zhang, P., Tsirakis, B., Kanchaveli, D. and LoSasso, T. (2019), Utilizing historical MLC performance data from trajectory logs and service reports to establish a proactive maintenance model for minimizing treatment disruptions. Med. Phys., 46: 475-483.

Chuang, K.-C., Giles, W. and Adamson, J. (2021), A tool for patient-specific prediction of delivery discrepancies in machine parameters using trajectory log files. Med. Phys., 48: 978-990.

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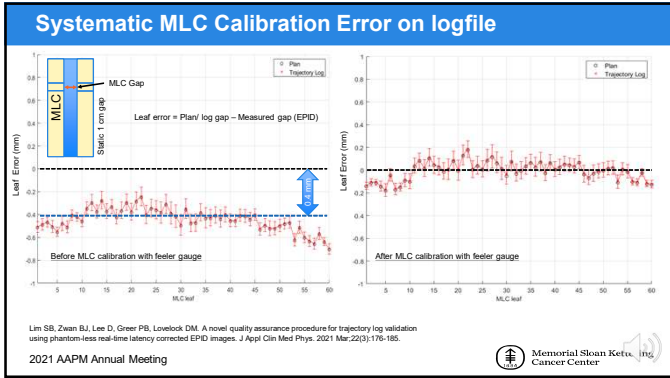### Log File Analysis Limitations
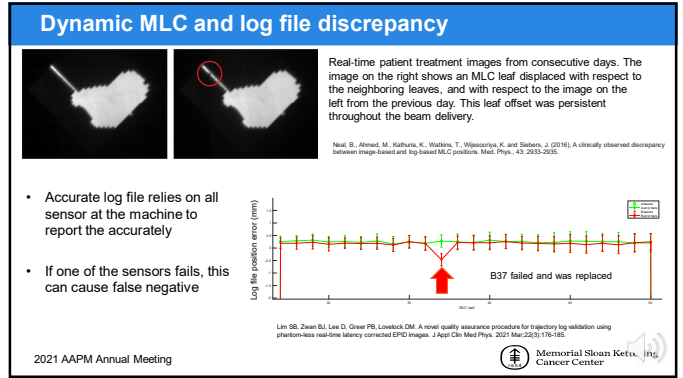
- Log file analysis depends on the commissioning and the calibration of
  - Mechanical system (including MLC, jaw, gantry… etc.)
  - Dosimetry tuning and output of the machine

- Dose Reconstruction
  - Accuracy of the beam model
  - Dose calculation algorithm of treatment planning system

- Data integrity

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Systematic MLC Calibration Error on logfile

MLC Gap

Leaf error = Plan/ log gap – Measured gap (EPID)

Before MLC calibration with feeler gauge

After MLC calibration with feeler gauge

Lim SB, Zwan BJ, Lee D, Greer PB, Lovelock DM. A novel quality assurance procedure for trajectory log validation using phantom-less real-time latency corrected EPID images. J Appl Clin Med Phys. 2021 Mar;22(3):176-185.

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Dynamic MLC and log file discrepancy

Real-time patient treatment images from consecutive days. The image on the right shows an MLC leaf displaced with respect to the neighboring leaves, and with respect to the image on the left from the previous day. This leaf offset was persistent throughout the beam delivery.

Neal, B., Ahmed, M, Kathuria, K., Watkins, T., Wijesooriya, K. and Siebers, J. (2016), A clinically observed discrepancy between image-based and log-based MLC positions. Med. Phys., 43: 2933-2935.

- Accurate log file relies on all sensor at the machine to report the accurately

- If one of the sensors fails, this can cause false negative

B37 failed and was replaced

Lim SB, Zwan BJ, Lee D, Greer PB, Lovelock DM. A novel quality assurance procedure for trajectory log validation using phantom-less real-time latency corrected EPID images. J Appl Clin Med Phys. 2021 Mar;22(3):176-185.

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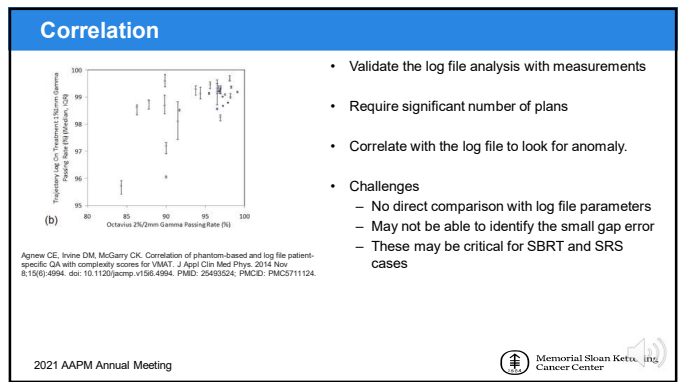Memorial Sloan Kettering Cancer Center

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Commissioning and QA

- Parameters
  - Most parameters, such as MU, can be checked with traditional technique using TG-142, MPPG 9a/8a, and TG-51
  - MLC can be challenging

- MLC
  - Initialization of the MLC
  - Static MLC log file QA
    - Feeler gauge
    - Graph paper / light field
    - High resolution 2-D array
      - Film
      - EPID

  - Dynamic MLC log file QA
    - Correlation technique
      - Measurement correlation with log file
      - Direct MLC comparison with log file difficult
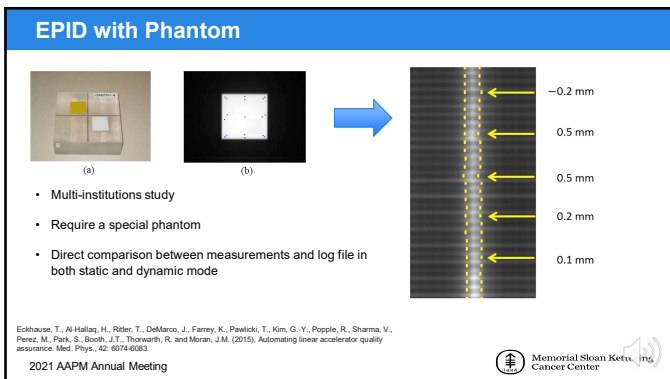   - EPID with Phantom
    - EPID Phantom-less

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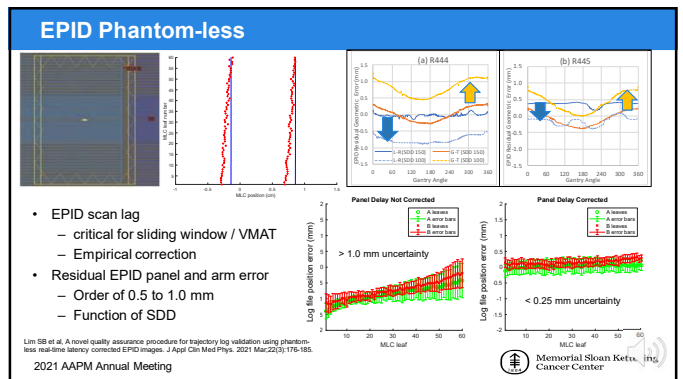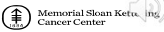
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Correlation

Agnew CE, Irvine DM, McGarry CK. Correlation of phantom-based and log file patient-specific QA with complexity scores for VMAT. J Appl Clin Med Phys. 2014 Nov 8;15(6):4994. doi: 10.1120/jacmp.v15i6.4994. PMID: 25493524; PMCID: PMC5711124.

- Validate the log file analysis with measurements

- Require significant number of plans

- Correlate with the log file to look for anomaly.

- Challenges
  - No direct comparison with log file parameters
  - May not be able to identify the small gap error
  - These may be critical for SBRT and SRS cases

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EPID with Phantom

(a)   (b)

−0.2 mm
0.5 mm
0.5 mm
0.2 mm
0.1 mm

- Multi-institutions study

- Require a special phantom

- Direct comparison between measurements and log file in both static and dynamic mode

Eckhause, T., Al-Hallaq, H., Ritter, T., DeMarco, J., Farrey, K., Pawlicki, T., Kim, G.-Y., Popple, R., Sharma, V., Perez, M., Park, S., Booth, J.T., Thorwarth, R. and Moran, J.M. (2015), Automating linear accelerator quality assurance. Med. Phys., 42: 6074-6083.

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EPID Phantom-less

(a) R444   (b) R445

- EPID scan lag
  - critical for sliding window / VMAT
  - Empirical correction
- Residual EPID panel and arm error
  - Order of 0.5 to 1.0 mm
  - Function of SDD

Panel Delay Not Corrected

Panel Delay Corrected

> 1.0 mm uncertainty

< 0.25 mm uncertainty

Lim SB et al, A novel quality assurance procedure for trajectory log validation using phantom-less real-time latency corrected EPID images. J Appl Clin Med Phys. 2021 Mar;22(3):176-185.

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Conclusions

- Log file analysis can provide automated and accurate delivery information

- Significantly streamline workflow and improve throughput

- High quality data can be used to build prediction models

- Calibration and sensor errors can provide false negative

- Proper commissioning and routine QA need to be performed to ensure the fidelity of the system

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Thank You

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