Patient QA
Recommended Publications
3DVH® Accuracy Studies


- Non-coplanar reconstruction accuracy study.

“Validation of measurement-guided 3D VMAT dose reconstruction on a heterogeneous anthropomorphic phantom,” D. Opp et al., JACMP 14(4), (2013)
- Accuracy study in heterogeneous phantom for lung VMAT plans with multiple ion chambers and film.
- Proof of concept for Respiratory MotionSim accuracy.

- Comprehensive explanation of the AC-PDP algorithm.
- Accuracy study with multiple ion chambers and film planes.

- Accuracy study of MC-PDP.

- Accuracy study of MC-PDP.

- Comprehensive description of Respiratory MotionSim algorithm.
- Accuracy study of Respiratory MotionSim with chamber and 3D comparisons.

“This should be considered a very good agreement indeed for a moving phantom, considering the additional uncertainties introduced by the motion.”

- Evaluation of 2D Gamma as a clinical metric versus 3D volumetric analysis.
- Accuracy study of MC-PDP.

- Evaluation of 3D Gamma as a clinical metric versus 3D volumetric analysis.
- Accuracy study using a white box test.
3DVH® Clinical Studies

“Evaluating IMRT and VMAT dose accuracy: Practical examples of failure to detect systematic errors when applying a commonly used metric and action levels,” B. Nelms et al., Med. Phys. 40 (11), (2013)

- Four separate hospitals submitted an article on errors they discovered using 3DVH but were missed by conventional planar Gamma analysis.

“Using a Novel Dose QA Tool to Quantify the Impact of Systematic Errors Otherwise Undetected by Conventional QA Methods: Clinical Head and Neck Case Studies,” M. Chan et al., Memorial Sloan-Kettering Cancer Center, Technology in Cancer Research & Treatment 2013 June 24

- Discovered both systematic and patient specific errors using 3DVH that were missed by Gamma QA. Used both EPIDose and film to verify all 3DVH discovered errors were true.

  - “The authors found that the Gamma criterion of 3%/3mm (or 2%/3mm) was too lenient to detect systematic errors, especially when used in TPS commissioning.”
  - “Our study has confirmed the importance of advancing from phantom Gamma-based to patient DVH-based IMRT dose QA. Other researchers have come to this conclusion as well.”
  - “Most of these errors would not be discovered in routine QA. Each potential source of error found by 3DVH has been verified to be relevant and true.” (Verified with film and EPIDose)


- Concludes that 5% DVH errors are missed with Gamma only analysis and that volumetric analysis is recommended for VMAT QA.

  - “It is recommended that the sole use of gamma index for Rapidarc QA plan evaluation could be insufficient and a methodology for evaluation of delivered dose to patient is required.”


- Clinical study showing lung SBRT VMAT plans are less effected by organ motion than IMRT treatments.


- Clinical study showing method for planned dose perturbation (PDP) for TomoTherapy.
- Nineteen plans were analyzed with varying complexity and concluded that PDP is capable of volumetric dose reconstruction with acceptable accuracy.
ArcCHECK® Accuracy Studies

“A comparison of the gamma index analysis in various commercial IMRT/VMAT QA systems” Mohammad Hussein et al., Radiotherapy and Oncology 109 (2013) 370–376

- Study comparing ArcCHECK, PTW 729, Delta4, MatriXX, and Gafchromic Film.
  “Out of all the systems, ArcCHECK measurements exhibited the closest statistical agreement with the predicted gamma index…”
  “Delta4 was found to have the lowest concordance coefficient based on measurements, indicating lower agreement with the predicted gamma index passing rate…”

“Robotic radiosurgery system patient-specific QA for extracranial treatments using the planar ion chamber array and the cylindrical diode array” Mu-Han Lin, Iavor Veltchev, Sion Koren, Charlie Ma, Jinseng Li, Univ of Maryland School of Medicine, Fox Chase Cancer Center, JACMP 16 (4), (2015)

- Study of ArcCHECK versus MatriXX for small field CyberKnife treatments
- Specifically compares Angular Dependence, Detector Accuracy, and Sensitivity to various errors on both devices.
  - Concludes diodes are more accurate for small field measurements

- Concludes ArcCHECK angular dependence is much lower than MatriXX, and therefore doesn’t require correction for CyberKnife treatments.
- Concludes ArcCHECK used at 2%/2mm criteria is superior at detecting Gantry Angle errors, Sup/Inf misalignments, MU changes, and Random Errors. Says MatriXX is superior at Left/Right misalignment detection only.


- Validates ArcCHECK for VMAT QA and Machine QA.
  “For the intentionally introduced systematic leaf positioning errors of −0.5 and +1 mm, the detected leaf positioning errors was −0.46 ± 0.14 and 1.02 ± 0.26 mm, respectively. This demonstrated the submillimeter sensitivity of the proposed method.”
- On a variable-gantry speed delivery, the Virtual Inclinometer showed “excellent agreement” and “accurate and high reproducibility of the Virtual Inclinometer”. In testing, it has a mean standard deviation of 0.03 seconds (<1 degree).
  “This method is efficient and an easy experimental setup. It is suitable for routine quality assurance of VMAT.”
  “…its cylindrical geometry and spiral pattern of diode distribution are also suitable for machine QA for VMAT”
  “There are also some studies using log files to perform VMAT QA. It is assumed that the actual delivery process is truly represented in the log files. The major disadvantage of this method is that Dynalog files need to be validated against an independent system.”
  “EPID was investigated for VMAT machine QA…..But as noted by the authors, that test contains all delivery parameters at once and does not allow easy distinction of the sources in case of problem occurrence.”
“Measurement comparison and Monte Carlo analysis for volumetric-modulated arc therapy (VMAT) delivery verification using the ArcCHECK dosimetry system,” M. Lin et al., JACMP 14 (2), (2013)

- Validation study of ArcCHECK for use with Cyberknife and non-coplanar beams.
- Found non-coplanar delivery makes a negligible difference below 20 degrees, and <1.2% difference up to 40 degrees.
  
  "We can therefore conclude that the impact of angular dependency for noncoplanar delivery is negligible."
  
  "Inherent to the (ArcCHECK) system is an assumption that center (target) dose is supposed to agree with the planned one if both the entrance and the exit doses agree with the predicted values. This assumption is certainly true."


- Multi-hospital study to validate that FFF delivery was accurate with ArcCHECK, Delta4, and MatriXX.
- States that a "device as MatriXX could not be the optimal choice" when high resolution is needed for small or highly-modulated fields.


- Validates ArcCHECK: Field size dependence, angular dependence, dose rate dependence, and intrinsic relative sensitivity (array calibration) factors, along with Virtual Inclinometer.

“Performance of the ArcCHECK-MRTM QA System in a transverse 1.5 T magnetic field," AC Houweling et al., Tech note (2014)

- Validates ArcCHECK-MR for the MR-linac: No significant differences between the performance of the MR-linac and the clinical linac were observed.
  
  "The short term reproducibility, dose linearity, dose rate dependence, field size dependence, dose per pulse dependence and inter-diode variation of the ArcCHECK-MR diodes were not influenced by the presence of a 1.5 T magnetic field. Therefore, the ArcCHECK-MR can be used for QA of patient plans in the MR-linac"

ArcCHECK® Clinical Studies

“Image-Guided Stereotactic Radiotherapy using the ArcCHECK Phantom,” O. Sauer, C. Groh, University of Würzburg, Germany, AAPM Poster 2013

- Validation of ArcCHECK as a fast end-to-end test for SRS.
  
  "The implemented test (ArcCHECK) is capable of quantifying the agreement between lasers and kV isocenter with discrepancies in the sub-mm range."
  
  "... pass rate of the gamma-criterion were well correlated to set-up errors"


- Evaluated iPlan’s PBC and MC algorithms for SRS/SBRT plans using ArcCHECK.
- ArcCHECK showed very good agreement on all Monte Carlo plans on a variety of SBRT body sites, with or without the plug.

“Patient-Specific Quality Assurance for the delivery of 60Co Intensity Modulated Radiation Therapy Subject to a .35-T Lateral Magnetic Field,” H. Harold Li et al., International Journal of Radiation Oncology Biology/Physics, (2014)

- Examines the use of ArcCHECK-MR as part of a patient-specific intensity modulated radiation therapy quality assurance (QA) program for ViewRay.
- AC-MR measurements indicated the mean SD passing rate using 3% relative/3 mm gamma criteria was 98.9%.
Patient vs. Phantom Geometry Studies


• 2D Planar Gamma passing rates shown to not correlate with clinically relevant errors.


• 3D and 3D volumetric Gamma passing rates still do not correlate well with clinical errors.

EPID vs. Log File Studies


• Study method: One year of picket fence data from 2 TrueBeams’ Trajectory log files vs. EPID images.

“Over the duration of the study, multiple MLC positional errors were detected using the EPID based software but these same errors were not detected using the trajectory log files.”

“In this study it was found that the trajectory logs created during the delivery of a picket fence test did not detect leaf positional errors that were detected using an EPID.”

“In this study it was found that the trajectory logs created during the delivery of a picket fence test did not detect leaf positional errors that were detected using an EPID.”
“Catching errors with in vivo EPID dosimetry,” A. Mans et al., Department of Radiation Oncology, The Netherlands Cancer Institute

- Detected 17 treatment errors out of 4337 treatments using an EPID based per fraction QA approach.
- 9 of the 17 would NOT have been detected by Pre-Treatment QA only.

<table>
<thead>
<tr>
<th>Error type</th>
<th>No. of errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient anatomy</td>
<td>7</td>
</tr>
<tr>
<td>Plan transfer</td>
<td>4</td>
</tr>
<tr>
<td>Suboptimally tuned TPS parameter</td>
<td>2</td>
</tr>
<tr>
<td>Accidental plan modification</td>
<td>2</td>
</tr>
<tr>
<td>Failed delivery</td>
<td>1</td>
</tr>
<tr>
<td>Dosimetrically undeliverable plan</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17</strong></td>
</tr>
</tbody>
</table>

- 7 of the 17 were attributable to patient changes/setup (the largest category of error), which a log-file solution alone will never be able to detect because it ignores the patient.
- Patient changes detected - weight loss, setup error, obstructions from table arms or immobilization devices, tumor or internal anatomy changes (postoperative cavity drainage, atelectasis shrinkage, etc.).
- 4 of the 17 were plan transfer issues – some with drastic errors resulting from MLC/Jaw erroneous syncing.

Furthermore, log file analysis is not completely independent, since it depends on the logging of data by the control system supplied by the equipment vendor, and would not detect, for instance, errors in the readout system itself.

For more information on the importance of measurements for Patient QA, ask for: “Measurement vs Calculation — What You Need to Know for QA and Patient Safety”