ArcCHECK® and 3DVH®

The Ultimate 4D Patient QA Solution

U.S. Patent No. 8,044,359; 6,125,335; 7,945,022

Your Most Valuable QA and Dosimetry Tools
ArcCHECK®

Cylindrical 4D Detector Array

ArcCHECK is the first truly 4D detector array specifically designed for arc, helical, and VMAT plan QA. The cylindrical design ensures that detectors remain coherent to the delivery beam regardless of angle. The geometry and detector size, along with software functionality, allow for high resolution and high density absolute dose measurements. The result is a very effective system for QA and dosimetry of all currently available clinical photon beams, including FFF.

Benefits

- 4D Patient Plan QA
- Patient Dose and Dose Volume Histogram analysis (3DVH® option)
- SunPoint® Diode Detectors
  - Smallest detector (0.000019 cm³)
  - Highest sensitivity
  - Proven stability
- Consistent Beams Eye View (BEV) for all gantry angles
- Measure composite dose, and control point ranges
- Measurement of every pulse
- Versatile cavity for detector inserts

Ease of Use

- Single power/data cable
  - Manages all power and data in one connection
- Integrated electronics
  - ArcCHECK is self-contained with no electronics to setup separately; and unlike 2D arrays, a separate phantom is not required
- Lightweight (16kg)
  - ArcCHECK is easily portable for daily use without the need for a separate cart
- Easy setup
  - Leveling LED’s provide real-time feedback on device rotation and tilt for a precise and easy setup
- Patented user calibration
  - Clinically proven Wide-Field Calibration (WFC) takes only 30 minutes and does not require disassembly of the ArcCHECK device
- No pre-irradiation
  - No pre-irradiation or warm-up required for absolute dose measurements

We are using the ArcCHECK for about a year now for QA of our clinical IMRT plans. On the basis of our experiences we can conclude that the ArcCHECK is not only suitable for the QA of Elekta linacs, but also for small stereotactic fields (up to 3x3 mm²) from a Novalis® linac (Brainlab).

Dr. Paul Rietveld, Ph.D.
Radiotherapiecentrum, The Netherlands
**Shape**
Phantoms are ideally shaped like a patient. The cylindrical design of ArcCHECK intentionally simulates patient geometry to better match reality.

**Coherent**
ArcCHECK® detectors and their angle of incidence remain coherent to the delivery beam regardless of angle. The BEV detector geometry does not change based on angle. When a 2D array is irradiated obliquely, the 2D array degrades to 1D. Even if there is no detector shadowing effect, significant information is lost on a 2D array.

**Geometry**
Detectors are arranged on a HeliGrid™ which increases the sampling rate and reduces BEV detector overlap and shadowing, compared to 2D systems.

- The central 10x10cm of the ArcCHECK contains approximately 221 detectors; the same as the MapCHECK® 2 10x10cm
- Entrance and exit dose are measured, effectively doubling the detector density in the measurement field
- Entrance and exit dose can be correlated with time to determine gantry angle

**Cavity**
ArcCHECK features a versatile central cavity for capturing dose in multiple locations including isocenter, if desired.

- With the cavity empty the ArcCHECK weighs only 16kg making it very easy to move and setup
- A cavity plug is available and may be used to accommodate different detectors and inserts
- The empty cavity and available inserts tests the TPS inhomogeneity planning
See the Entire Picture with ArcCHECK®

Below is what a 2D array and ArcCHECK will capture for the same plan measurement. ArcCHECK highlights areas that would not normally be captured with a 2D array. Measure and correlate gantry angle, leaf end position, absolute dose and time (4D) to identify the source of errors. Error sources may include the TPS, delivery system, imaging system, setup, or MLC.

What you see with a 2D array

2D Array Measurement
With a 2D array, only a fraction of dose information is available; this is an inherent limitation in 2D arrays.

What you see with ArcCHECK

ArcCHECK Measurement
ArcCHECK displays BEV dose distribution throughout the entire arc delivery. More data is available to perform a more thorough QA analysis.

Beam Delivery

ArcCHECK Detector BEV (Beams Eye View)

10 x 10cm
230 Detectors

21 x 21cm
1386 Detectors
Hardware that is Easy to Setup and Use

ArcCHECK® contains a sophisticated yet easy to use leveling system that ensures set up is quick and easy. With built in rotation and tilt inclinometers, the ArcCHECK can relay setup status in real-time.

Virtual Inclinometer™

For any delivery, ArcCHECK will calculate the gantry angle independently using the unique Virtual Inclinometer. This enables correlation of dose and time with angle (4D). The Virtual Inclinometer is accurate to ±0.5°, and avoids additional inclinometer cables and mounting to the delivery system.

Calibration

Array

ArcCHECK utilizes a patented wide field calibration method (US Patent No. 6,125,335) that only requires calibration once per year or even less frequently. The process takes approximately 30 minutes. In clinical use since 1996, Sun Nuclear’s calibration method offers several key benefits:

- The instrument does not need to be returned to the factory for re-calibration
- The user may independently verify the accuracy of the calibration
- The calibration does not require a flat beam
- Calibration files are not linac specific
- The unit does not need to be disassembled

Dose

ArcCHECK absolute dose calibration is similar to the proven MapCHECK® 2 method. The ArcCHECK is positioned with its axis coincident to SAD, utilizing the coronal and sagittal lasers. A 200 MU beam with a 10x10cm field is delivered to the device. Known dose at the detector location (89.6cm SDD) is entered to arrive at an absolute dose correction, applicable to all ArcCHECK detectors. The process takes approximately one minute to complete prior to arc delivery QA.
Stringent Interior Measurements

ArcCHECK® measures entry and exit dose for every angle. Measuring completely around the isocenter in a uniform manner for each angle is a more stringent measurement than a simple composite dose at the isocenter. Errors visible in the isocenter can also be visible in the surrounding dose measurements, but in more detail.

For each beam angle, ArcCHECK measures high dose regions at the entrance and low dose regions at the exit, detecting potential delivery and TPS modeling errors for both high and low dose levels. For those who would like to measure the dose at isocenter or elsewhere within the cavity, Sun Nuclear offers the versatile MultiPlug and CavityPlug with detector insert.

Features

- Hounsfield conversion testing
- Precision fitted to ArcCHECK cavity
- Inhomogeneity insert options:
  - Muscle
  - Bone
  - Lung
  - Adipose
  - Titanium
- Measure dose in cavity center
- Dose in up to 25 unique locations including the isocenter
- Film cassette insert
- Bezel angle indicator for rotation within cavity
- PMMA (acrylic) construction
- Precision milled detector holder included
- Solid insert included to achieve solid cavity

MultiPlug™

ArcCHECK shown with the optional MultiPlug for measuring dose at up to 25 locations including the isocenter.

Features

- Precision fitted to ArcCHECK cavity
- Measure dose in cavity center
- PMMA (acrylic) construction
- Precision milled detector holder included
- Solid insert included to achieve solid cavity

CavityPlug™

ArcCHECK shown with the optional CavityPlug for measuring dose at isocenter.
SNC Patient™ Software

The ArcCHECK® interface is SNC Patient software, a powerful and proven patient QA and analysis tool with over 2000 clinical installations.

- The same analysis and workflow options from MapCHECK® 2 are available in ArcCHECK
- All data files from ArcCHECK are in an open format for easy export, including raw data
- ArcCHECK QA plans are in three dimensions. DICOM RT Dose is imported and a 3D dose grid corresponding to detector locations is extracted for comparison to measured.

With a single mouse click, SNC Patient Software compares measured dose points to planned dose points. Users can compare normalized data or absolute dose data using Distance To Agreement (DTA) or Gamma ($\gamma$).

Three adjustable criteria guarantee maximum flexibility and are easily adjusted. Measured points that do not fit within the acceptance criteria are highlighted red for high dose and blue for low dose.
Control Point Analysis with ArcCHECK® and SNC Patient™ Software

Scrutinize arc plans using Control Point Analysis. Individual control points and user-defined arc sections can be analyzed for a full arc or sub arc. A unique polar graph with movie playback offers a 360° presentation of pass, low, and high dose summary for the defined control point range and sub arcs.

Publications


3DVH transforms the field of per-patient dose QA by generating clinically-relevant and intuitive analyses of complex IMRT and VMAT plans. With proven accuracy, 3DVH estimates the 3D dose to the patient-specific geometry. Powered by the patented Planned Dose Perturbation (PDP™) algorithm, 3DVH uses existing QA measurements. Clinicians can abandon abstract and unpredictable “passing rate” metrics and instead use the same methods to QA treatment plans as those which were used to create them.

Benefits

- Transform 2D measurements to 3D dose volume for advanced analysis
- Perform 3D dose and DVH QA analysis on patient – not phantom – geometry
- Supports coplanar and non-coplanar beams
- Identify TPS and beam delivery errors
- Intuitive and familiar presentation of dose and DVH with statistics per anatomical structure
- Fast results with automated tools – Quick Stat Templates, Quick Dose Profiles, DICOM compliant workflow
- No forward dose calculation into the patient CT
- No commissioning
- Uses existing measurements and devices
- With optional Respiratory MotionSim™ module, analyze the dosimetric impact of a moving target

Sun Nuclear’s 3DVH software offers a unique quality assurance tool for patient specific IMRT QA. Testing was conducted for IMRT plans where we introduced known errors in both absolute dose and geometry of the delivered fields. These differences were accurately detected and reported by 3DVH and gave us a high degree of confidence in the system’s ability to detect treatment delivery errors. The system also revealed that where beams may “pass” in a 2D analysis, regions of failure and match were more clearly revealed in a 3D analysis.

Kym Rykers Ph.D.
Chief Radiation Oncology Physicist, Austin Health, Australia

1 See Publications, Page 13
The Problem: 2D QA is not strongly correlated to actual errors

Actual Errors versus 2D Gamma Passing Rate
Perfect correlation of 2D QA Gamma Passing Rate (%) and Actual Error in DVH Metric is desired.

2D: A Lack of Correlation
Commonly accepted 2D QA Gamma Passing Rate lacks significant correlation to actual errors in a patient geometry. While 2D QA techniques are useful for QA, 2D QA Gamma Passing Rates are not reliable as an estimator of actual error in a treatment plan.


3D Volumetric with 3DVH: Significant Correlation
When QA measured errors, large or small, are used to create an estimated 3D dose volume in a patient geometry for QA comparison, significant correlation is achieved.

False Positive and False Negative

False positive occurs when the analysis suggests an error, but the delivery is consistent with plan. Here is an example of false negative - a serious issue as the delivery passes the criteria but misses the intended dosage.

SNC Patient™ software with 2%/2mm criteria showing 95.3% passing rate

SNC Patient software with 3%/3mm criteria showing 99.2% passing rate

Evaluating the same plan, 3DVH shows substantial target underdose.
Respiratory MotionSim (RMS) allows the clinician to simulate the dosimetric impact of target motion with proven accuracy. Extending the patented 3DVH® 4D dose perturbation methodology, RMS allows the physicist to define motion trajectories and quantitatively evaluate the impact of organ motion on dose distribution. RMS is an important tool for clinicians committed to evidence-based decision making and quality assurance of highly-modulated radiation therapy treatments where organ motion is a concern.

Features and Benefits

- Uses proven Planned Dose Perturbation (PDP™) measurement-guided reconstruction method to estimate dynamic 4D dose
- Evaluate both 3D Dose and DVH changes caused by motion to determine if motion management is necessary, and to QA motion management plans
- Use existing QA measurements and avoid bulky and attenuating mechanical motion phantoms
- Run simulations virtually and modify motion, including randomization, with one click
- Fully integrated with 3DVH Release 3.0
- No commissioning required
- See RMS datasheet for more information

Motion Management in Three Steps

1. Generate high resolution 4D dose grids automatically as part of the 3DVH and ArcCHECK® PDP process

2. Define patient-specific contours from 4D CT images

3. Simulate and compare dose DVH of moving target vs. stationary target by analyzing 3D dose, DVH, or point doses vs. time

Publications

Respiratory MotionSim


ArcCHECK, MapCHECK® 2 and 3DVH

- “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), 111722 (2013)

3DVH

- “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., Technology in Cancer Research and Treatment (2013)

1 Requires ArcCHECK® and 3DVH
Machine QA with ArcCHECK® and SNC Patient™ Software

Save time and improve accuracy. Use ArcCHECK for a wide variety of machine QA tests in dynamic and rotational mode.

Dynamic Gantry Rotation QA*

Dynamic Gantry Angle QA*

Dynamic Gantry Speed QA

Dynamic Symmetry and Flatness*

MLC QA

Treatment Reproducibility QA

*Also available with static angles
SunPoint® Diode Detectors – The Right Choice for QA & Dosimetry

Smaller detectors provide pinpoint-sized sampling of dose data, which detects errors over an entire field, both in and out of gradient. Attempts to measure the entire field by increasing the detector size creates a blurred measurement in dose gradients. Such measurements are counter-productive to accurate and useful dose sampling.

Chambers
Ion chamber measurements lack high resolution, resulting in a blurred measurement

EPID/Film
EPIDs and film have good density and resolution; however absolute dose, accuracy, reproducibility and uniformity need to be verified

Diodes
Diodes are capable of accurate, reproducible high-resolution measurements. ArcCHECK® uses SunPoint Diode Detectors

2 x 2cm field profile measurements with various detectors
Small size = more precision, less averaging
ArcCHECK® Specifications

Detector Type: SunPoint® Diode Detectors
Detector Quantity: 1386
Detector Spacing (cm): 1.0
Array Diameter (cm): 21.0
Array Length (cm): 21.0
Cavity Diameter (cm): 15.0
Inherent Buildup (g/cm²): 3.3
Inherent Backscatter (g/cm²): 3.3
Detector Physical Depth (cm): 2.9
Array Geometry: Helical Grid (HeliGrid™)
    1cm offset
Phantom Material: PMMA (Acrylic)
Active Detector Area (mm²): 0.64
Detector Sensitivity (nC/Gy): 32.0
Max Dose/Pulse (Gy): 0.003
Detector Volume (cm³): 0.000019
Detector Stability: 0.5%/kGy at 6MV
Dose Rate Dependence: ± 1%, 75 - 250cm SSD
Update Frequency (ms): 50
Number of Connection Cables: Single power/data cable
Dimensions (cm²)/Weight (kg): 27.0 x 43.0 / 16.0

System Requirements (SNC Patient™, 3DVH®)

Operating System: Windows XP, Windows 7
CPU (GHz): Recommended 2.4 or better, multi-core (2 or more cores)
RAM: Recommended 4GB or more
Hard Drive Space: Recommended 5GB or more

ArcCHECK Compatibility

• Rotational Therapy: RapidArc®, VMAT, TomoHelical™
• Static Gantry: IMRT, TomoDirect™
• Treatment Planning Systems: Pinnacle®, Eclipse®, Monaco®, iPlan®, and any TPS system that can export DICOM data
• FFF & non-FFF Deliveries

3DVH Compatibility

• Hardware: ArcCHECK, MapCHECK® 2,
• Software: EPIDose™, SNC Patient (included)
• Rotational Therapy: RapidArc®, VMAT
• Static Gantry: IMRT
• Treatment Planning Systems: Pinnacle®, Eclipse®, and most TPS systems that can export DICOM data (TomoTherapy® coming soon)
• FFF & non-FFF Deliveries