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
Benefits
› 4D Patient plan QA
   – RapidArc, VMAT, TomoTherapy, and SmartArc
› 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 needed
› 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

Compatible With
› FFF Beams
› VMAT
› RapidArc®
› TomoTherapy®
› Pinnacle® SmartArc™

Testimonial
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
A Cylindrical Design is Most Appropriate for Arc Delivery Applications

**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.

**Shape**

Phantoms are ideally shaped like a patient. The cylindrical design of ArcCHECK intentionally emulates patient geometry to better match reality.

**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 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
With ArcCHECK, See the Entire Picture

Below is what a 2D array and ArcCHECK will see for the same plan measurement. ArcCHECK highlights areas that would not normally be seen with a 2D array. Measure and correlate gantry angle, leaf end position, absolute dose and time (4D) to identify the source of the error. Error sources include a TPS, delivery system, imaging system, setup, and 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 inherent with all available 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 21 x 21cm
230 Detectors 1386 Detectors
Virtual Inclinometer™

For any delivery, ArcCHECK will calculate the gantry angle independently using a 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 typically requires calibration every one to three years. 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 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
› 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
› Included precision milled detector holder
› Included solid insert for completely solid cavity

*Photons only
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 are available in ArcCHECK
- All data files from ArcCHECK are 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.

1. **Compare.** Measure, then click compare to see the results against the planned file
2. **TH.** Isodose percentage line that defines the dose area to evaluate
3. **% Diff.** Percent acceptance criterion between Set 1 and Set 2 dose values
4. **Distance.** Distance-to-agreement criterion
5. **% Pass.** Percentage of detector points that passed within the defined threshold with a pass/fail indication
6. **Calc Shift.** Determines a misalignment between measured & planned dose maps and automatically corrects if accepted by the user
Control Point Analysis

Scrutinize arc plans via ArcCHECK’s Control Point Analysis feature. 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.
3DVH® – Clinically-Relevant QA with Proven Accuracy

U.S. Patent No. 7,945,022

3DVH uses existing QA results to compare delivered and planned patient dose-volume histograms without the complications of a secondary dose algorithm. It takes QA from phantom to patient geometry using the proven Planned Dose Perturbation (PDP™) method. PDP perturbs the 3D treatment plan using differences between measured and expected phantom doses. The process produces a 3D dose reconstruction of the actual dose delivered to patient anatomy. The patented PDP process has been proven accurate in independent research (see subsequent list of publications).

2D: A Lack of Correlation

Recent research indicates passing rates are not a relevant metric for QA. Commonly accepted 2D QA Gamma Passing Rates lack 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.

Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors


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.

Moving from gamma passing rates to patient DVH-based QA metrics in pretreatment dose QA

3DVH Benefits

› Takes QA from 2D to Volumetric 3D
  - Uses measurements from ArcCHECK®, MapCHECK® 2, or EPIDose™ to create an estimated 3D dose volume for QA comparison
  - Uses criteria commonly used in the clinic, such as DVH for targets and critical structures

› From Phantom to Patient
  - Differences from expected and measured doses in the phantom are used to perturb the 3D treatment plan to estimate actual patient dose

› Delivers Fast Results
  - No commissioning required – simply select your linac, energy and MLC combination
  - 3DVH is only a QA process and not a secondary patient dose calculation engine
  - Ability to import CT overlay for display purposes is included but not required

› Proven Accuracy
  - Independent publications have proven that 3DVH predicted errors correlate to actual errors, whereas 2D predicted errors lack significant correlation to actual errors in a patient geometry

Features

› Using real QA measurements to estimate 3D dose in patient
› Compare DVH, slice, and absolute point dose of estimated 3DVH vs. TPS
› Supports coplanar and non-coplaner beams

› Customizable DVH “Quick Stats” for your department
› Uses ArcCHECK to analyze:
  - gantry angle vs. time
  - cumulative or differential dose vs. time
  - MLC measured positions vs. predicted positions
› Automatically corrects for depth, SSD, and patient geometry
› Includes all major Linac/MLC/energy beam models (no commissioning)

With the 4D Workspace, view cumulative and instantaneous ArcCHECK dose and correlate to gantry angle and MLC position.

3DVH Publications

› “Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors” B. Nelms et al, Med. Phys. 38, 1037 (2011)
› “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, Technol Cancer Res Treat, Epub ahead of print (2013)
Respiratory MotionSim™

**Applications**
- Respiratory / breathing dosimetric effects simulation
- Prostate motion simulation (including non-cyclical)
- Gating dosimetric effects simulation

**Benefits**
Within the 3DVH® software and using the standard ArcCHECK® setup, Respiratory MotionSim allows quantification of patient specific motion effects on 3D dose distribution in patient anatomy.
- No additional setup or phantom required
- Motion effects are fully patient specific
- Dose distributions in patient anatomy and geometry
- Up to 5 dose reconstructions per second
- No commissioning

**FAQ**

**Does ArcCHECK measure the isocenter dose?**
ArcCHECK measures entry dose before the isocenter, and exit dose after the isocenter at two effective depths 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 will also be visible in the surrounding dose measurements, but in more detail. For those who would like to measure the dose at isocenter or target, Sun Nuclear offers cavity plug options with detector inserts.

**Can the ArcCHECK measure in absolute dose?**
SunPoint Diode Detector based instruments measure the absolute dose accurately with the dose calibration of the reference detector to the standard accelerator output, exactly as an ion chamber device would do.

**What is the purpose of the ArcCHECK cavity?**
- The cavity may always be filled with the ArcCHECK CavityPlug, however if left empty the cavity tests the ability of the TPS to calculate plans with air cavities and inhomogeneities. This approach offers another way of doing QA on the TPS/delivery system. All modern treatment planning systems should be capable of creating a plan on the ArcCHECK without the CavityPlug option inserted. Without the CavityPlug inserted, there are still several centimeters of scatter material above and below the detectors.
- Easy to transport/lightweight.
- Dose in up to 25 unique locations including the isocenter with MultiPlug™.

**What is the angular dependence of ArcCHECK?**
ArcCHECK offers an angular compensation feature which results in negligible angular dependence ($\leq\pm1.0\%$).

**What is the largest field ArcCHECK can measure?**
The length and diameter of the ArcCHECK array is 21cm. Although with beam divergence, this array covers a field length of 23cm (at isocenter). Field sizes up to 36cm are supported with the merge feature.

**Respiratory MotionSim Publications**
- “Motion as a perturbation: Measurement-guided dose estimates to moving patient voxels during modulated arc deliveries” V. Feygelman et al, Med Phys, 40 (2013)
- Experimentally studied dynamic dose interplay does not meaningfully affect target dose in VMAT SBRT lung treatments” C. Stambaugh et al, Med Phys, 40 (2013)
Machine QA

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 Rotation QA](image)

**Dynamic Gantry Angle QA***

![Dynamic Gantry Angle QA](image)

**Dynamic Gantry Speed QA**

![Dynamic Gantry Speed QA](image)

**Dynamic Symmetry and Flatness***

![Dynamic Symmetry and Flatness](image)

**MLC QA**

![MLC QA](image)

**Treatment Reproducibility QA**

![Treatment Reproducibility QA](image)

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

Smaller detectors provide pinpoint sized sampling of dose data proven to detect 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, uniformity and reproducibility need to be verified.

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

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2 x 2cm field profile measurements with various detectors

**Scanning ion chamber**
Active volume: >6000x that of diode

**SunPoint Diode Detector**
Active volume: 0.000019cm²

Small size = more precision, less averaging
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)
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
Radiation measured: Photons: Co-60 or linear accelerator produced
Number of connection cables: Single power/data cable
Dimensions (cm²) / Weight (kg): 27.0 x 43.0 / 16.0
Operating system: Windows XP, Vista, 7 (32 or 64 bit)
Computer Requirements:
4GB RAM, 1 available USB 2.0 port, Dual-core processor (2.4GHz or higher), 5GB hard disk space, 32MB VRAM video card, 32-bit color depth, OpenGL hardware accelerated

ArcCHECK Publications

- “Novel dosimetric phantom for quality assurance of volumetric modulated arc therapy”
- “Optimizing the accuracy of a helical diode array dosimeter: A comprehensive calibration methodology coupled with a novel virtual inclinometer”
- “The ArcCHECK diode array for dosimetric verification of HybridArc”