Quality assurance with OCTAVIUS Detector 1600 SRS

at the CyberKnife®

PTW THE DOSIMETRY COMPANY

Introduction

The CyberKnife® is a high precision robotic radiosurgery device for stereotactic treatments. Because of the small target volumes and the high doses it is important that the system guarantees a high accuracy. It is fundamental to perform quality assurance (QA) regularly.
A workflow is presented to use the liquid-filled OCTAVIUS Detector 1600 SRS ionization chamber array for quality assurance at the CyberKnife®, especially for patient-specific QA, as well as for Iris QA and to perform the Laser and Radiation Coincidence Check. In the first step, the angular dependence of the detector was evaluated for typical CyberKnife® beam paths to quantify the effect of non-normal beam incidence. This step is performed once and does not have to be repeated by the user. In the second step, the detector was used for patient-specific QA, Iris QA and the Laser and Radiation Coincidence Check. The clinical workflow for these measurements is described in this document.

Angular Dependence of OCTAVIUS Detector 1600 SRS

To analyze the angular dependence of the OCTAVIUS Detector 1600 SRS, the expected dose for two common CyberKnife® paths, Head Path and Body Path, was calculated by the TPS and measured with the OCTAVIUS Detector 1600 SRS. The deviation in percent between the measured dose of the central chamber of the detector and the expected dose was calculated and visualized in this plot.

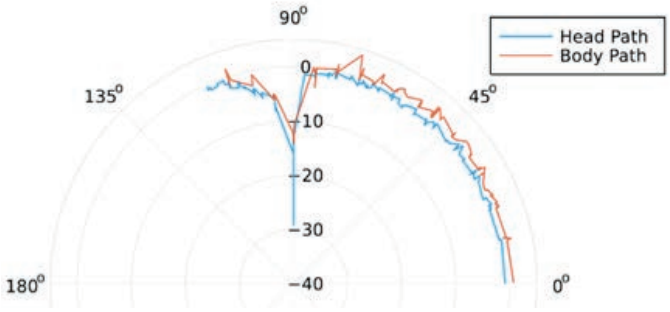

Figure 1: Angular response of the OCTAVIUS Detector *1600 SRS*

To present the angular dependence, spherical polar coordinates were used. The displayed angle is always the spherical angle between the detector normal and the incident beam vector. Therefore the plotted spherical angle of 90° can be a 90° or 270° angle if you compare it with a normal accelerator that can only rotate in one plane. For the CyberKnife®, the use of spherical polar coordinates is more useful, because there are more degrees of freedom.
This plot shows that the angular dependence of the OCTAVIUS Detector 1600 SRS is quite small and only for 90° there is a larger deviation. This means that only for this angle, the measurement result will be influenced by the angular dependence of the OCTAVIUS Detector 1600 SRS. Usually, there are many different angles in treatment plans, so the deviation at 90° will be negligible for the total measurement result, because the dose distribution will be the sum of all the irradiated nodes.

Patient-specific QA

To perform patient-specific QA the first step is to create a CT scan of the measurement setup. The measurement setup consists of some RW3 plates for backscattering (for example 5 cm), the OCTAVIUS Detector 1600 SRS array and the CyberKnife® marker plate (part of the PTW CyberKnife® package) on top. The marker plate has integrated fiducials so it is used for the automatic alignment and also as buildup material.
Import the CT data in the treatment planning system (TPS). Use this CT data to create a QA phantom as described in the user manual of the TPS. This QA phantom will be used for all the treatment plans to perform patient-specific QA.
By using the OCTAVIUS Detector 1600 SRS it is necessary to perform a cross-calibration before starting the measurement. Independent from this cross-calibration some small field corrections concerning dose rate or field size might be necessary. It is possible to determine the reference value for this cross-calibration by an ionization chamber measurement or by using the TPS. The easiest way to perform this cross-calibration is to create a cross-calibration plan with one beam perpendicular to the OCTAVIUS Detector 1600 SRS with a defined field size and dose and determine the expected dose of the central chamber of the OCTAVIUS Detector 1600 SRS. Then create the Patient QA plan to be measured in the TPS (as described in the TPS user manual) using the patient plan and the QA phantom. Select the fiducial tracking method. It might be necessary to adjust the alignment, so that the dose to be measured is centered in the high resolution area of the OCTAVIUS Detector 1600 SRS.
Hint: To save measurement time and dose, you can scale down the dose.
Hint: To adjust the dose distribution to the areas of low and high resolution it can be advantageous to create contours representing these areas in the phantom template.

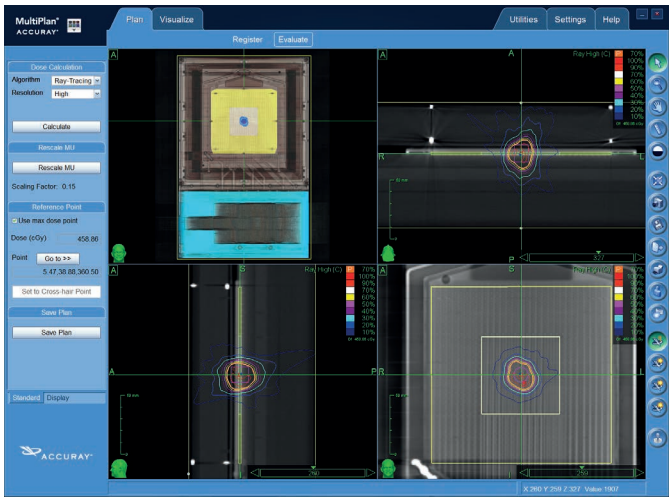

Figure 2: Patient QA plan alignment on the OCTAVIUS Detector

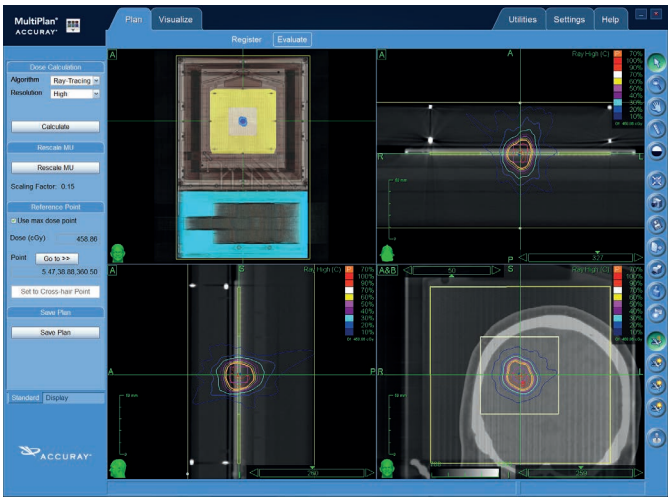

Figure 3: Same Patient QA plan as in Figure 2 but with the patient CT

Calculate the patient QA plan with high resolution. Store the patient QA plan as a deliverable plan so that it can be irradiated. Additionally, it is necessary to export the RT dose data to compare the measurement. The calculated data should be exported as a full 3D dose distribution.

Put the measurement system on the patient couch. Be aware to use the same measurement setup as in the CT scan.

Figure 4: Measurement setup for patient-specific QA

Figure 5: Alignment of the measurement setup

After the cross-calibration, start the measurement of the patient QA plan.
For both the cross-calibration and the treatment plan, use the CyberKnife® imaging system for automatic alignment.

Hint: During the measurement, it is recommended to disable the imaging to save time. It is not necessary to have imaging during the measurement, because the measurement setup is not moving.

Figure 6: Automatic fiducial alignment

After the measurement, it is possible to compare the measured dose to the planned dose using VeriSoft and the gamma analysis, and to individually select the appropriate gamma criteria for the measured application. The measurement area always represents a coronal plane through the 3D dose cube. The appropriate slice depth for the comparison has to be defined once for the selected phantom template. To determine the right depth in a 3D dose distribution, a coronal 2D dose plane may be exported from the QA plan, representing the plane of measurement in the detector array.
Gamma evaluation may be performed using a 2D or 3D gamma criterion.
Hint: Patient-specific QA can also be performed on a CyberKnife® with a multi leaf collimator because the requirements are the same as for the fixed and iris collimator.

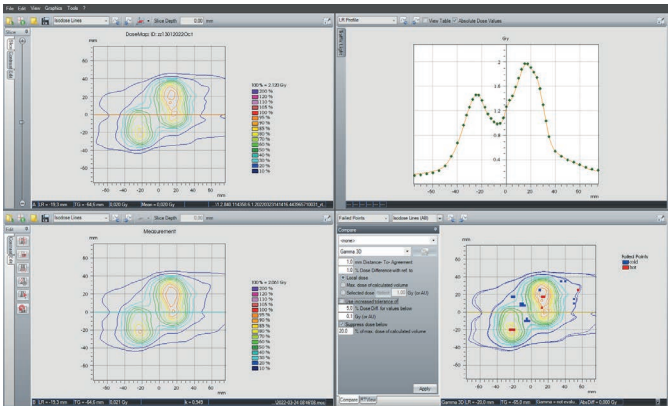

Figure 7: Plan evaluation in VeriSoft

Iris QA

The CyberKnife® has an iris collimator that can vary the circular field size. It is important to check the reproducibility of the different field sizes. For this purpose, the OCTAVIUS Detector 1600 SRS is a useful tool.
To perform an Iris QA-measurement the same phantom setup as for patient-specific QA may be used.
The baseline data should be measured with an iris collimator system in a calibrated state, at best during or shortly after commissioning of the collimator system.
A QA plan is prepared in the treatment planning system, using the CT data set of the phantom setup and the iris collimator system. For every selectable field size, a single beam perpendicular to the OCTAVIUS Detector 1600 SRS measurement plane has to be created using sufficient MU to get a reproducible measurement (e.g. 200 MU).
The CyberKnife® will be automatically aligned perpendicular to the array using the fiducials information and the different field sizes will be irradiated. For every field size a single measurement file should be stored.

For the evaluation of the measurement, use the software BeamAdjust with the profile view. There it is possible to analyze the field size for the main axes and the diagonals. Even for the smallest 5 mm field size the measurement can be used as a system stability check.

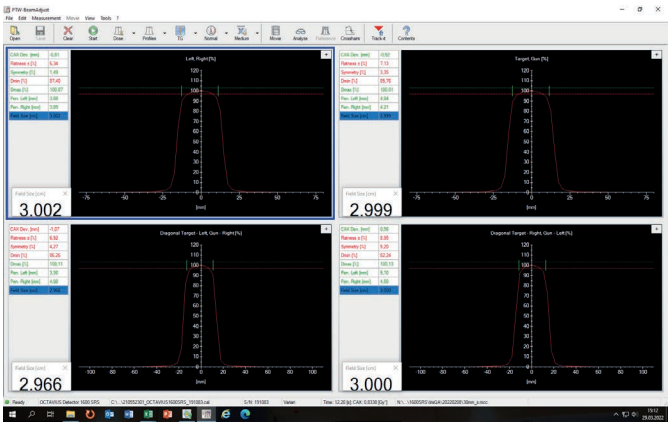

Figure 8: Measurement evaluation in BeamAdjust

Additionally, it is possible to compare a reference measurement with the current measurement using VeriSoft. Comparing the isodose distribution of the reference data with the actual measurement even small field size deviations down to 0.1 mm are easily detected. To enable this evaluation, the two measurements should be rescaled to the same absolute dose.

A gamma evaluation is not recommended, as it is sensitive to the measured values of the single array chambers which may show major deviations due to alignment differences. The actual field size is better represented through the interpolated isodose lines.
This measurement is a constancy check. This means that it is important that the results are always the same with a small tolerance. The absolute value is not important.

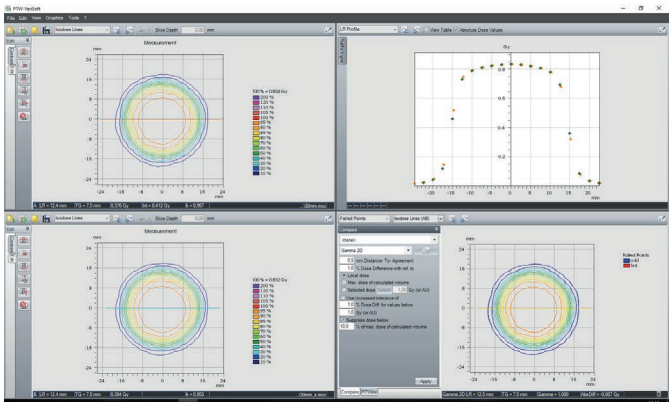

Figure 9: Measurement evaluation in VeriSoft

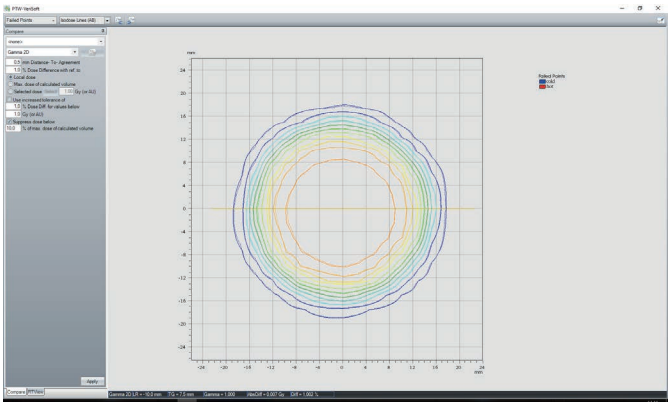

Figure 10: Comparison of the isodose distribution

Collimator/Laser and Radiation Coincidence Check

Another regularly performed QA is to check the coincidence of the collimator laser and the collimator beam axis. To perform this measurement, it is important to align the OCTAVIUS Detector with the laser. The laser must be positioned on the central chamber using the pinhole collimator accessory.

After the alignment, irradiate the OCTAVIUS Detector with a predefined field size from two different heights.
Analyze the measurement with BeamAdjust. In BeamAdjust in the profile view it is possible to analyze the central axis deviation. This deviation should be below predefined values, depending on the surface-distance as recommended by the manufacturer.

Figure 11: Measurement setup for the Laser and Radiation Coincidence check

Figure 12: Measurement setup for the Laser and Radiation Coincidence check with the double height

Conclusion

The clinical workflow of performing patient-specific QA and machine QA with the OCTAVIUS Detector 1600 SRS at the CyberKnife® was presented.
Because of the negligible angular dependence of the OCTAVIUS Detector 1600 SRS it is possible to use it for patient-specific QA and to measure a two dimensional dose distribution with a high resolution. Additionally, the fast measurement setup means machine QA, in form of iris QA and the Laser and Radiation Coincidence Check, is fast and user-friendly.

References

Quality assurance for a replaced IRIS collimator system on a CyberKnife M6 – (C. Albrecht et al) Abstracts - BMTMedPhys 2017 – Dresden, September 10–13

Patient-Specific Quality Assurance in a Multileaf Collimator-Based CyberKnife System Using the Planar Ion Chamber Array - (J. Yoon et al) Progress in Medical Physics 29(2), June 2018

High resolution ion chamber array delivery quality assurance for robotic radiosurgery: Commissioning and validation - (O. Blanck et al) Physica Medica, Volume 32, Issue 6, 2016, Pages 838-846

Authors

Nicole Brand
Product Manager and
Medical Physicist,
PTW Freiburg GmbH

Christian Albrecht
Medical Physicist,
CyberKnife Centrum Süd
Schwarzwald-Baar
Klinikum
Villingen-Schwenningen

Britta Loutfi-Krauß
Medical Physicist,
CyberKnife Centrum Süd
Schwarzwald-Baar
Klinikum
Villingen-Schwenningen

Ordering information

CyberKnife® packages
L981627 OCTAVIUS I, 1600 SRS
T43037 Marker plate CyberKnife®

PTW Freiburg GmbH
Lörracher Str. 7
79115 Freiburg · Germany
Phone +49 761 49055-0
info@ptwdosimetry.com
ptwdosimetry.com

D913.208.01/00 2022-08

PTW THE DOSIMETRY COMPANY