Volumetric Modulated Arc Therapy

- Patient Specific QA

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VMAT plan QA methods

Composite dose measurement
- Film & ion chamber
- diode array
  - Mapcheck in MapPhan phantom
  - ArcCheck
  - Delta4
- 2D ion chamber array
  - MatriXX in MULTICube phantom
  - PTW 729 in Octavius phantom

Fluence measurement
- 2D ion chamber array
- MatriXX mounted on Gantry
- Portal dosimetry
Which system do you use/intend to use in your clinic for VMAT QA

0%  A. Film & ion chamber
0%  B. Ion chamber array (MatriXX, PTW 729)
0%  C. Diode array (mapcheck, ArcCheck, Delta4)
0%  D. Portal dosimetry
0%  E. others
A stack of solid water phantom with a total thickness of 15cm.

A 0.6cc farmer chamber was inserted at the depth of 10cm.

A film was sandwiched 1cm above the ion chamber.
Ion Chamber measurement is 1.3% below the predicted value
H&N Case
H&N Case: absolute dose comparison

- The Gamma analysis passing rate in this case is 96.4%
- The measured ion chamber dose was 0.2% more than the planned one
2D Diode Array

A MapCheck device inserted into a MapPhan solid water phantom
MapCheck in MapPhan QA result

- With 3% and 3mm criteria, the gamma analysis passing rate is 96.5%
- Dose threshold in gamma analysis is 10%
The variation of dose response with the dose rate can reach up to 2.5% for MapCheck diode.
Calibrate MapCheck with medium dose rate

Dose calibration was performed at 224 MU/Min

Gamma passing rate increased to 98.8%
Angular dose response of MapCheck diode

Significant variation of the dose response can be found when the incidence beam angle is parallel to the detector plane.

Each diode in MapCheck may have different angular dose response curve.
Arc Check – Sun Nuclear

- 1386 diode detectors arranged in cylindrical geometry
- Measures entrance and exit dose
- The QA can be done in composite or per control point
Central Cavity Options

- ArcCHECK features a versatile central cavity
  - May be used to accommodate different detectors and inserts
  - MultiPlug (left) also accommodates EBT film cassette and multiple detector locations
SNC Patient Software

- Software enables composite and control point analysis
- DICOM RT Dose is imported and ArcCHECK software then extracts 3D dose corresponding to detector locations, and performs a comparison
- All data files from ArcCHECK are open format for easy export
  - Raw data also available for export
Gamma analysis passing rate is 95.2% for this case.
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 ±1°, and avoids additional inclinometer cables and mounting to the delivery system.
3DVH Option

- The most advanced 3D patient dose and DVH tools available
  - Uses existing ArcCHECK measurements
  - Supports VMAT and RapidArc deliveries
  - No secondary dose calculation algorithm
  - 3D dose and DVH analysis on patient geometry (not phantom geometry)
Scandidos Delta⁴

- A cylinder-shaped plastic phantom with 2 imbedded orthogonal crossing detector planes.
- 1069 diode detectors
- Dose is recorded in 2 planes and a 3D dose is reconstructed for comparison with the QA plan.
Composite-level analysis of SmartArc plan with Delta$^4$
MatriXX & MULTICube phantom

- MatriXX system has 1020 vented ion chambers with an active area of 24.4cm x 24.4cm.

- The size of each ion chamber is 4.5cm (diameter) x 5cm (height). The raw pixel size is 7.62mm, which can be interpolated down to 1mm.

- Laser is used to align system. Dose from both coronal and sagittal planes can be measured depending on the phantom.
MatriXX data conversion

The raw image has only 1024 pixels with 7.62mm dose grid. The data set can be interpolated to 1mm dose grid.
Results: Prostate Case

With 3% and 3mm criteria, the passing rate is 99% for this coronal slice.
MatriXX QA: H&N Case

With 3% and 3mm criteria, the passing rate is 98.2% for this coronal slice.

No dose threshold was applied in gamma analysis. Note the passing rate reduces to 97.1% if a 10% threshold is applied.
Angular variation of dose response

- Up to 8% dose variation can be found when the photon beam is parallel to the detector plane.
The gantry angle for each frame is recorded during the VMAT delivery.

A angular dose response correction is applied to all the data based on the gantry angle information.
With and Without Angular response correction

The measured data without angular dose response correction is slightly colder than the one with correction.
With and Without Angular response correction

Without Correction 81.9%
With Correction 96.2%

3% and 3mm passing criteria for Gamma analysis.
Which of the following cannot be measured using MatriXX 2D ion chamber array

0% A. Dose distribution on a sagittal plane
0% B. Absolute dose at detector center
0% C. Dose distribution on a coronal plane
0% D. Dose distribution on a transverse plane
0% E. Radiation fluence of a VMAT plan
Answer

A. Dose distribution on a sagittal plane
B. Absolute dose at detector center
C. Dose distribution on a coronal plane
D. Dose distribution on a transverse plane
E. Radiation fluence of a VMAT plan
Portal Dosimetry

Portal Dosimetry Process

- Created verification plan for each patient
- Calibrated panel prior to collecting data
- Data measured in units of CU

Definition of Calibrated Unit (CU)
- Field Size = 10 x 10 cm²
- SDD = 105 cm
- Deliver 100 MU to panel
- Set reading = 1 CU
  1 CU is numerically approximate to 1 Gy
Portal Dosimetry – RapidArc (Prostate)
Portal Dosimetry – RapidArc (Prostate)
Portal Dosimetry – RapidArc (HN)
Portal Dosimetry – RapidArc (HN)
Which QA system has the highest resolution

0%  A. portal dosimetry using EPID
0%  B. film
0%  C. MatriXX 2D ion chamber array
0%  D. ArcCheck
0%  E. Delta4
Answer

A. portal dosimetry using EPID
B. film
C. MatriXX 2D ion chamber array
D. ArcCheck
E. Delta4
Summary

- VMAT QA using film and ion chamber is easy to setup and perform. However, there is no instantaneous result and it is time-consuming for data analysis.

- Diode-array and ion-chamber-array based devices can provide instantaneous data analysis and can be used for VMAT patient specific QA once the angular dose response and dose rate dependence is considered during data analysis/collection.

- Portal dosimetry can provide an easy and robust way for patient specific QA. The only issue with this technique is that information on gantry angle cannot be checked independently.

- Users need to know limit of each QA technique/device for best patient specific QA result.
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