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Patient-related QA for helical TomoTherapy with Delta4: analysis of the results

Abstract: The biplanar diode arrays Delta4PT and Delta4+ has been used in our hospital since the introduction of the TomoTherapy in 2013 to ensure a good agreement between the calculated and the measured dose distributions in patient-related QA with helical TomoTherapy. The aim of this presentation is to evaluate the quality of the measurement procedure with the Delta4 phantoms Delta4PT and (since January 2016) Delta4+. This includes the influence of a cross calibration with a treatment plan with low modulation.

Two analyses were performed: (i) All treatment plans in a period of three months (n=86) were not only calculated and measured with Delta4PT or Delta4+ but also with an ionization chamber (Exradin A1SL) in the homogeneous "cheese phantom". (ii) All data measured from January 2016 to April 2017 (Delta4+, n=132) were analyzed regarding median dose deviation, Gamma analysis and others.

The comparison with chamber measurements shows that all measurements with Delta4 and almost all with the ionization chambers (79 of 86) yield a deviation of measured vs. planned dose in the PTV of less than 2.5%, but with a lower variation of the Delta4 measurements. However, a strong correlation between both was not observed.

The separate analysis of the measurements with the newer Delta4+ (since January 2016) shows a mean dose deviation in the PTVs of only 0.14% with a standard deviation (S.D.) of 0.69%. Before every measurement a cross calibration has been performed. Without this cross calibration, the deviation would be 0.96% with an increased standard deviation of 0.93%.

It is concluded that the Delta4 systems are well suited for patient-related QA for helical TomoTherapy treatment plans. The comparison with chamber measurements shows a plausible accordance between both systems whereas the variation of single measurements is quite different.

With the help of a daily cross calibration the variability of the Delta4 results is further decreased and the results show higher accuracy and reliability. According to our experience, a daily cross calibration is mandatory for a reliable patient-related QA.

Keywords: TomoTherapy, 2D-Dosimetry, Delta4, quality assurance

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1 Introduction

The biplanar diode arrays Delta4PT and Delta4+ offer an accurate and efficient verification of IMRT, VMAT and TomoTherapy plans. It has been used since the introduction of the TomoTherapy in 2013 to ensure a good agreement between the calculated and the measured dose distributions in patient-related QA with helical TomoTherapy. Until this day more than 1000 treatment plans were checked with the Delta4PT, since January 2016 with the Delta4+. In June 2016 we decided to measure only every 4th patient treatment plan, because of the implementation of a system for independent dose calculation in clinical routine. If extreme plan parameters are used an additional measurement is performed as well.

The diode arrays Delta4PT and Delta4+ contain 1069 diodes with a size of 1mm x 0.05 mm² (radial x axial). An advantage of this system is the division of the full dose into the dose entries per gantry angle segments. So some correction factors can be taken into account for each detector, for instance for beam direction and for phantom depth. After the measurement the results of the comparison with the treatment plan are seen a few seconds later without extra steps (dose deviation, distance-to-agreement, Gamma-analysis, 3D-DVH).

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The aim of this presentation is to evaluate the quality of our measurement procedure of the patient treatment plans with the Delta4 itself. This procedure includes not only the measurement of the patient plan but also a daily cross calibration. So the influence of ageing of the diodes, the daily machine output, temperature, air pressure and possible errors during the absolute calibration can be reduced. The Delta4 software allows the estimation of a daily correction factor.

For the analysis of our system we performed different investigations. Two of them are presented here.

Firstly, all treatment plans in a period of three months (between October 2015 and January 2016) and additionally some previous measurements with higher deviation were calculated and (re-) measured with Delta4 and additionally with an ionization chamber (ExradinA1SL, Standard Imaging Inc.).

Secondly, all treatment plan measurements (not all patients) with the newer Delta4+ from the introduction in January 2016 till April 2017 were analyzed to find out accuracies with and without a daily cross calibration. Therefore, we investigated the results with and without the cross calibration.

2 Materials and methods

2.1 Workflow

The patient-related quality assurance starts with the recalculation of the treatment plan onto the own dataset of the delta4 phantom with own HU-table correction. The measurement itself starts daily with a cross calibration onto a treatment plan with a homogeneous cylindrical high dose volume (diameter and height 6cm), created with low modulation and verified dose. Because all inner diodes are used for the estimation of the daily correction factor, they are situated completely in the high dose region (see figure 1). The mean deviation in this area is used as a correction factor for the further measurements performed on this day.

2.2 Chamber measurements

For the dose measured with ionization chambers (Exradin A1SL, Standard Imaging Inc.), the mean value of two chambers at two points in the high dose region in the homogeneous “cheese phantom” is used. The preparation is similar to Delta4 measurements: the treatment plan is recalculated onto own CT data set of the phantom, for the cross calibration the same simple treatment plan is used respectively. The daily correction factor measured here was was always less than 0.5%.

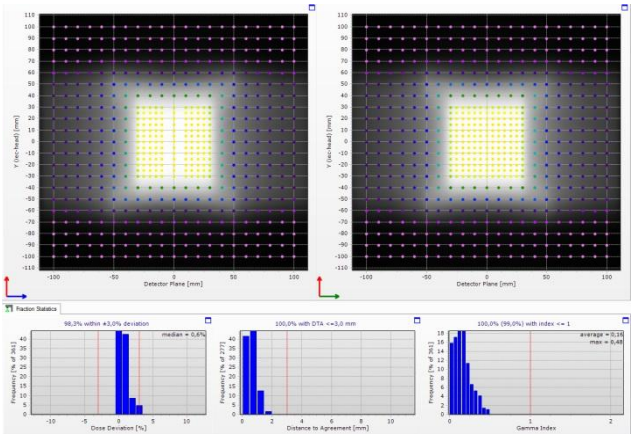

Figure 1: Cross calibration plan shown in the Delta4 platform

2.3 Criteria to accept a measured plan

For clinical routine we decided to compare the dose in the higher dose region (more than 60% of measured Dmax), primarily. The Gamma-index (global, 3%/3mm) is observed as well. Although a 3D calculation is included as well, this option is not yet used.

A plan is accepted if the median dose deviation of the diodes which receive more than 60% of Dmax is smaller than 3% and no outlier in the Gamma histogram occur. Otherwise the deviation is always discussed with a physician. In some cases it was necessary to prepare a new treatment plan.

3 Results

The results of the comparison between chamber measurements on a “representative” position in the PTV and Delta4 measurements are presented in figure 2. It is seen that all measurements with Delta4 and almost all with the ionization chamber (79 of 86) yield a deviation of measured vs. planned dose in the PTV of less than 2.5%. The mean values are 0.52% (S.D. 1.08%) for Delta4 and -0.50% (S.D. 1.49%) for chamber measurements, but a strong correlation between both measurements was not observed.

The separate analysis of the measurements with the newer Delta4+ (since January 2016, n=132) shows a mean dose deviation in the high dose region of 0.14% (S.D. 0.69%). Without this cross calibration, the deviation would be 0.96% with an increased standard deviation of 0.93%. The factor derived from cross calibration (daily correction factor) itself, has a mean value of 0.991 (S.D. 0.70%). Figure 3 shows the deviation of all of them including cross calibration.

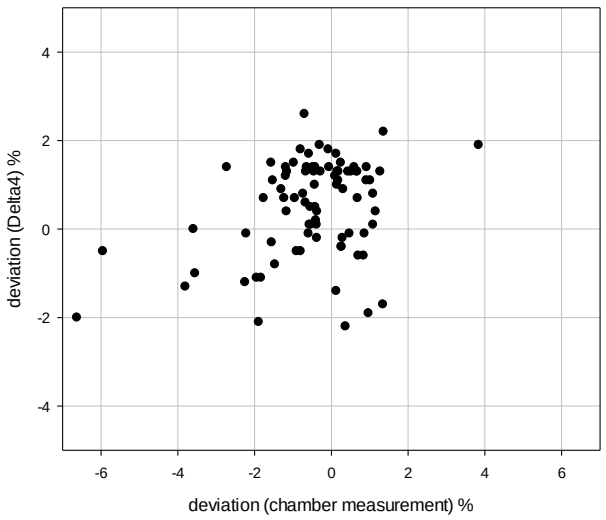

Figure 2: Deviation of Delta4 measurements vs measurements with the ionization chamber. For the Delta4 measurements the median dose deviation of all point with >60% of Dmax is used. Chamber measurements show the mean of 2 positions.

Using the Gamma index method most measured points fulfil the criteria (global, 3%/3mm) completely (n=108 of 132) or almost completely (from 99% to <100%: n=14, from 97% to <99%: n=6). Only in 4 cases the Gamma criteria were failed for more than 5% of the detectors.

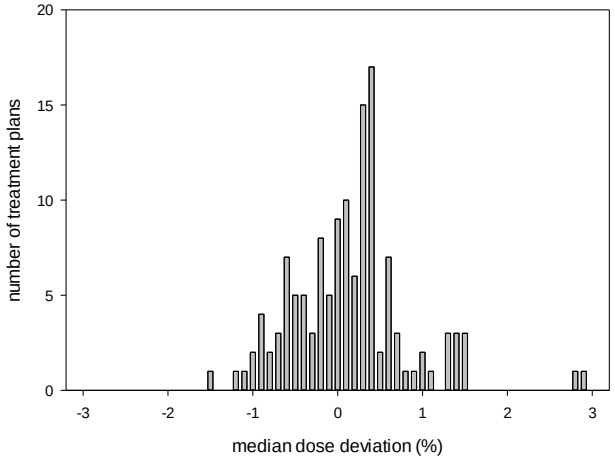

Figure 3: Deviation of all measurements with Delta4+ according to our procedure with included cross calibration.

4 Discussion

4.1 Comparison with chamber measurements

Figure 2 show some chamber measurements which are outside 2.5% dose deviation. This is possibly because of a small field size (jaw opening 1cm, 2 of 6), small target volumes (2 other of 6) or just the chance of the positioning of the chamber to meet a homogeneous area. With a mean or median dose of hundreds of detectors this effect should be smaller as are given in the Delta4.

Another fact is that there is no obvious correlation between the results of the two types of dosimetric systems. There are cases with overdosage at the chamber positions and underdosage in the median dose of the Delta4 and vice versa. The mean values are in a magnitude of ±0.5%, which is very similar to each other. We conclude that there a randomly variations, which are quite larger if only one or two points are considered.

4.2 Workflow and cross calibration

Dose deviations in patient QA measurements are caused by different errors or influences: planning system, machine output, other machine uncertainties e.g. MLC travelling time and leaf opening time and the detector system, respectively. The cross calibration should reduce unintentional influences from the detector system (calibration factor, diode sensitivity), the daily machine output and external conditions (temperature, pressure). In this way changes in the sensitivity can be neglected as well as errors during the calibration of the detector system. On the other hand errors coming from the planning system or the MLC (MLC travelling time, leaf opening time) have to be detectable. The use of a comparatively simple treatment plan as a daily correction factor plan fulfils these requirements sufficiently.

Our measurements show, that the Delta4 system is well suited for patient-related QA for helical TomoTherapy treatment plans. The comparison with chamber measurements shows a plausible accordance between both systems whereas the variation of single measurements is quite different. With the use of a daily cross calibration with a comparatively simple treatment plan as a daily correction factor plan, the influence of unintended errors can be reduced, so that our dose variation in the high dose region contains approximately 0.7% (standard deviation). According

to our experience, a daily cross calibration is mandatory for a reliable patient-related QA.

Author's Statement

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