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TECHNICAL NOTE

Implementation of the Calypso system: a commissioning experience

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ABSTRACT

Background: The aim of this study was to describe the clinical implementation of the Calypso system with its potential impact on the treatment delivery.

Materials and methods: The influence of the electromagnetic array was investigated on the kilovoltage cone beam computed tomography (kV-CBCT) image quality using the CATPHAN 504 CBCT images. Then, the QFix kVue Calypso couch top and the array attenuation, and their dosimetric influence on the Volumetric modulated arc therapy (VMAT) treatments of prostate was evaluated.

Results: Regarding the image quality, a significant increase of noise ($p < 0.01$) was detected with the array in place, resulting in a significant decrease in signal noise ratio (SNR) ($p < 0.01$). No difference in absolute contrast was observed. Finally, there was a significant decrease in contrast noise ratio (CNR) ($p < 0.01$) even if the deviation was only of 2.5%. For the dosimetric evaluation, the maximum attenuation of the couch was 12.02% and 13.19% for X6 and X6 flattening filter free (FFF), respectively (configuration of rails out). Besides, the mean attenuation of the array was 1.15% and 1.67% for X6 and X6 FFF, respectively. For the VMAT treatment plans, the mean dose was reduced by 0.61% for X6 and by 0.31% for X6 FFF beams when using the electromagnetic array.

Conclusions: The Calypso system does not affect significantly the kV-CBCT image quality and the VMAT plan dose distribution.

Key words: Calypso; electromagnetic tracking; commissioning

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Introduction

The Calypso 4D Localization System (Varian Medical Systems, Inc., Palo Alto, CA, United States) is a real-time target tracking system consisting in an electromagnetic transponder detection for patient alignment and online target position tracking. Many studies have demonstrated the submillimeter precision of this electromagnetic tracking system for translational and rotational offsets [1–3] but few studies have used the Calypso in clinical trials. The Montpellier Cancer Institute is the first center to consider pelvic late toxicity rate for the prostate treatment when using the Calypso System in a randomized phase II trial called RCMI-GI [4]. The Calypso was installed in our department on this occasion.

Beyond the Calypso performance largely described in the literature [5–7], this report details

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the commissioning experiments to evaluate its potential impact on the treatment delivery.

Materials and methods

Image quality

In the framework of the RCMI-GI trial, a cone beam computed tomography (CBCT) was performed prior to the treatment for every patient [4]. Kilovoltage cone beam computed tomography (kV-CBCT) was, therefore, performed with the electromagnetic array in place and the specific Calypso couch top. Consequently, the image quality could be impaired by the system. kV-CBCT images of a CAPTHAN 504 were acquired using the pelvic mode (120 kV and 80 mA) with and without the array to evaluate this impact. Image quality was evaluated using the signal to noise ratio (SNR), the absolute contrast and the contrast to noise ratio (CNR).

SNR was calculated as

$$SNR = \frac{x_{ROI}}{\sigma_{ROI}}$$

where x_{ROI} and σ_{ROI} are the mean and the standard deviation of the pixel intensities inside a circular region of interest (ROI). The ROI was drawn in the uniform material of the CTP-486 module on 10 sequential slices, and x_{ROI} and σ_{ROI} were measured.

The CNR and the absolute contrast were evaluated in the CTP-401 sensitometry module and defined as:

$$CNR = \frac{x_{target} - x_{background}}{\sqrt{\sigma^2_{target} + \sigma^2_{background}}}$$

where x and σ are the mean and the standard deviation of the pixel intensities inside a circular ROI. A ROI was drawn on each of the eight targets available, and x and σ were measured on 10 sequential slices.

Wilcoxon matched pairs tests were used to study the influence of the array on the several parameters. Results were considered significant for $p < 0.05$. Finally, the correlations between the density of the different targets and the difference of SNR between image acquired with and without the array were investigated using a Spearman's rank order correlation.

Dosimetric influence

In the same way as the electromagnetic array and the couch top could affect the quality image they could also influence the dose distribution. First, the QFix kVue Calypso couch top and the array attenuation was evaluated by comparing the dose measurements with Eclipse TPS dose prediction for 2 energies [6MV flattening filter (FF) and 6MV flattening filter free (FFF)] and 2 rail configurations (rails in and rails out). Dose measurements at the isocenter were performed with a cylindrical water-equivalent phantom and a 0.125cc ionization chamber (PTW 31010). The phantom was positioned on the Calypso couch and the electromagnetic array was placed above it as shown in Figure 1. The alignment to the isocenter was adjusted with a kV-CBCT. Thirty-nine 10 x 10 cm² fields were performed with an angular resolution from 5° to 15°/measurement (Fig. 1). The beams between 315 and 45° allowed analyzing the electromagnetic array attenuation. The beams between 90 and 270° were used for the whole couch attenuation.

Secondly, the dosimetric impact was analyzed on 20 VMAT treatment plans of prostate (10 with 6MV FF and 10 with 6MV FFF). Dose distributions were recalculated in the cylindrical phantom and the dose prediction at the isocenter was compared to the dose measurement with the 0.125 cc ionization chamber with the Calypso system in the case of RCMI-GI treatment: QFix kVue Calyp-

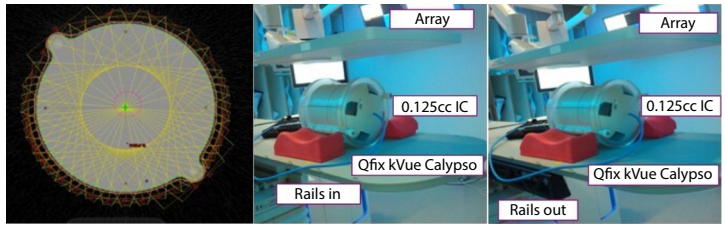

Figure 1. Evaluation of the dose attenuation with 2 rails configurations: rails in (left) and rails out (right)

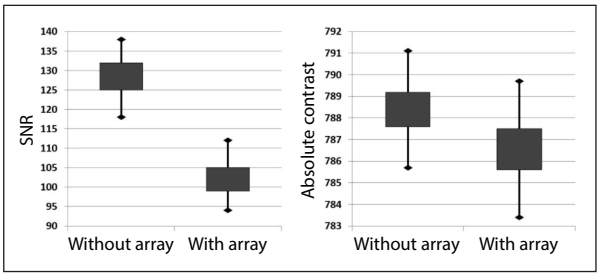

Figure 2. Comparison of the signal noise ratio (SNR) (left) and the absolute contrast (right) with the introduction of the electromagnetic array in the treatment beam

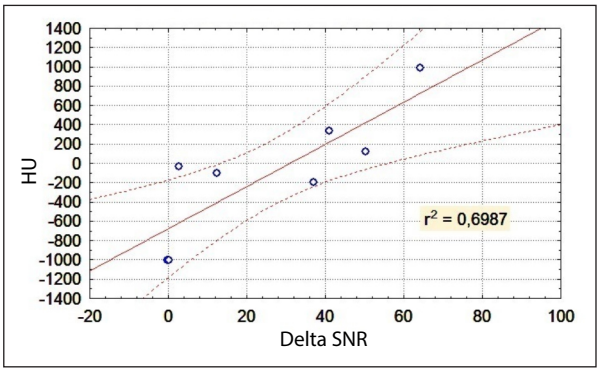

Figure 3. Correlation between signal noise ratio (SNR) and the Housfield unit (HU) of materials available in CTP-401 module

so couch top with rails out and the electromagnetic array in place.

Results

Image quality

The SNR was evaluated in the CTP-486 module. The 10 sequential images analysis reported no significant signal differences between images acquired with and without the array. But there was a significant increase of noise ($p < 0.01$) when the array was positioned between the source and the phantom, resulting in a significant decrease in SNR ($p < 0.01$) as shown in Figure 2. Moreover, the CNR was decreased with the introduction of the electromagnetic array. Nevertheless, the absolute contrast was only reduced by 2.5% (Fig. 2). Using the CTP-401 module, this loss in SNR was investigated in function of the material density. Results are displayed in Figure 3 and showed to be positively correlated with an increasing density of the target ($p < 0.05$, $R^2 = 0.699$).

Dosimetric influence

The attenuation data relative to the gantry rotations for the 2 configurations (rails in and rails out) are shown in Figure 4. In the configuration of rails out, the mean attenuation of the couch was 2.91% for X6 and 3.45% for X6 FFF with a maximum of 12.02% and 13.19% for X6 and X6 FFF, respectively. In the configuration of rails in, the mean attenuation was 3.25% for X6 and 3.90% for X6 FFF with a maximum of 9.79% and 11.14% for X6 and X6 FFF, respectively. Besides, the beams between 315 and 45° allowed analyzing the electromagnetic

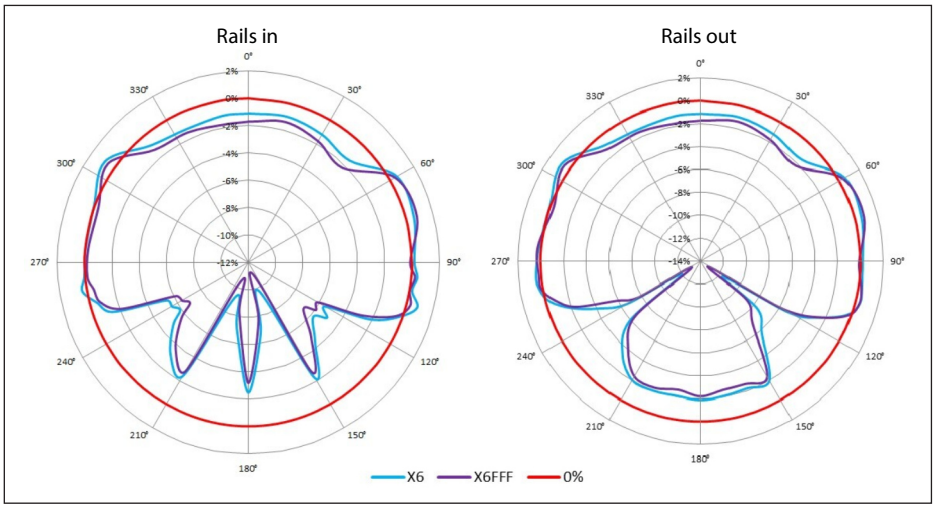

Figure 4. Attenuation results in function of the gantry angle with two rails configurations in 6MV flattening filter (FF) and 6MV flattening filter free (FFF). The red line represents zero attenuation

array attenuation. It was 1.15% and 1.67% for X6 and X6FFF, respectively.

The impact of global Calypso system (QFix kVue couch top with rails out and the electromagnetic array) on VMAT treatment plans was evaluated, too. The mean deviation between the dose prediction and the dose measurement was –0.61% (–0.8%; –0.3%) for X6, and –0.31% (–0.86; 0.43) for X6FFF.

Discussion

The introduction of the electromagnetic array increases the noise within kV-CBCT images, without significantly degrading the absolute contrast. The impact on the accuracy patient positioning should be limited. To date, our data are the first to evaluate the kV-CBCT image quality with the whole Calypso system (QFix kVue couch top and the electromagnetic array). Only Ye et al. [8] exhibited an abstract about the assessment of the Calypso tabletop for CBCT imaging. They compared CBCT acquisitions between the carbon fiber tabletop and synthetic fiber tabletop. Imaging characteristics were equivalent for both designs.

The dosimetric tests revealed an important attenuation for the fixed beams crossing the rails. However, the QFix kVue flat couch top and the electromagnetic array attenuate the 6MV FF and 6MV FFF beams less than 2%. Moreover, the prostate VMAT plans were not significantly affected by the introduction of this device. Our results are consistent with other studies [9–11].

Conclusion

The introduction of Calypso system in the treatment beam did not significantly affect the delivery quality: kV-CBCT images were slightly altered with an increase of the noise, without degrading the absolute contrast and the dosimetric influence may be considered negligible for VMAT treatments.

Conflicts of interest

The authors declare there are no conflicts of interest.

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