

VALIDATION OF A PRE-TREATMENT DELIVERY QUALITY ASSURANCE METHOD FOR THE CYBERKNIFE SYNCHRONY SYSTEM

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OBJECTIVE



The purpose of this work was to evaluate the **dosimetric accuracy** of the **CyberKnife Synchrony Respiratory Tracking System (RTS)** and to validate a method for **pre-treatment patient-specific delivery quality assurance (DQA)**.

MATERIALS AND METHODS

An **EasyCube Phantom** (Sun Nuclear Co), consisting of RW3 tissue-equivalent slabs, was mounted on the **ExacTrac (ET) Gating Phantom** (BrainLAB AG), which can move along the superior-inferior axis of the patient to simulate a moving target. Eight fiducial markers were implanted in the EasyCube for the treatment set-up and for the tracking. A **Gafchromic EBT3 film** (Ashland Inc) was positioned between two slabs of the EasyCube, while a **PinPoint ionization chamber** (PTW GmbH) was placed in an appropriate insert. The EBT3 films were calibrated with a 6MV beam (Trilogy, Varian) from 0 to 15 Gy and analyzed with the **multichannel film dosimetry** performed by the FilmQA Pro software (Ashland Inc). Our evaluation was performed in two steps:

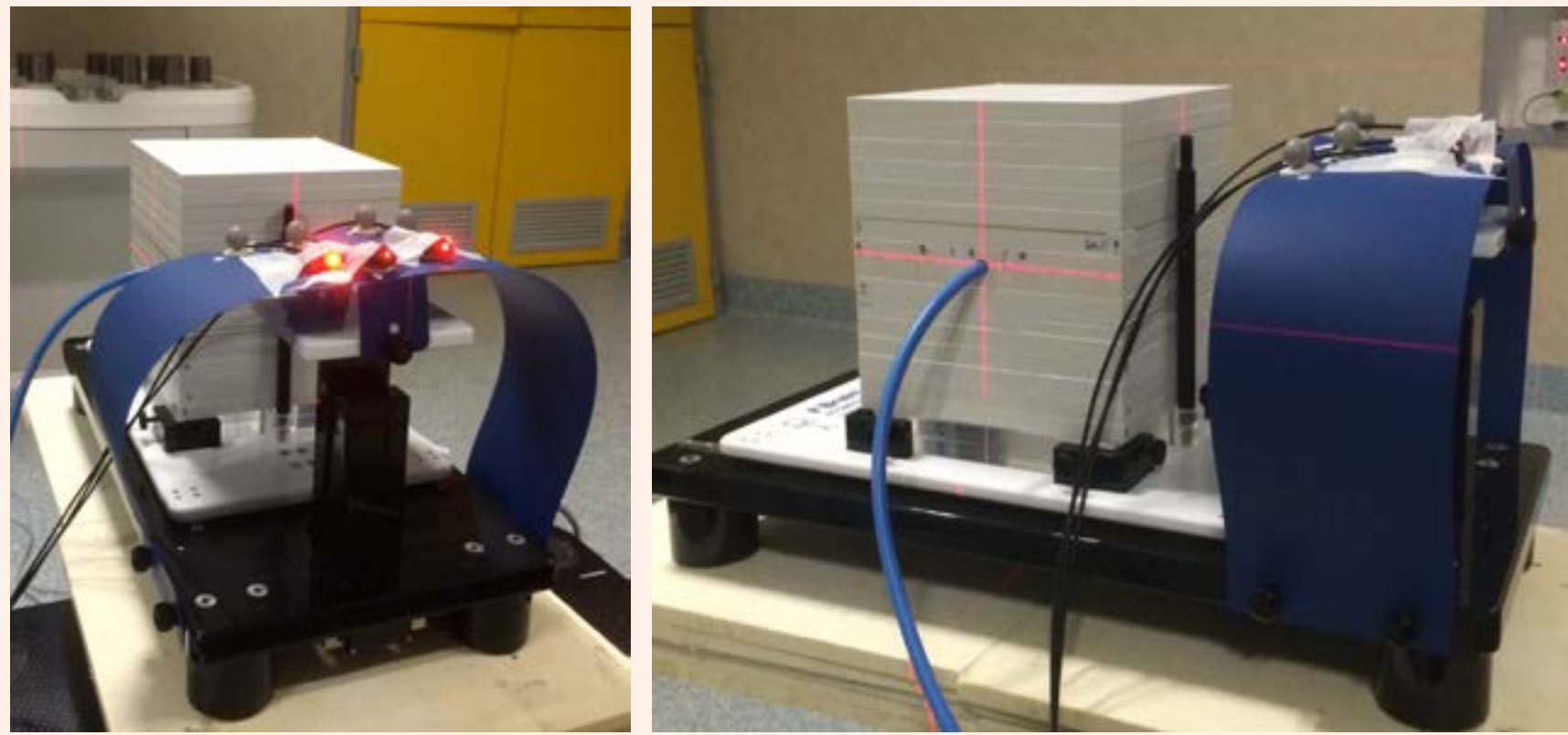


Fig. 1. Experimental set-up: EasyCube phantom mounted on the ExacTrac Gating phantom.

- The films were irradiated with **single fields** perpendicular to the EasyCube using several collimators (3 fixed collimators: 15, 30, 60mm; 3 IRIS aperture sizes: 20, 30 and 40mm) and **different dynamic conditions**, varying the shape, the period (T) and the amplitude (A) of the internal movement of the ET Phantom. Sinusoidal patterns with A of 8, 14 and 28 mm and T of 2, 4, 5 and 6 s were used. The delivered dose distributions were compared with the planned ones, using the **gamma (γ) analysis** method. The local γ passing rates (GP) were evaluated using 3 acceptance criteria, varying the local dose difference (LDD), the distance-to-agreement (DTA) and the dose threshold (TH) of the γ function: **1) 3%/3mm TH=10%; 2) 2%/2mm TH=30%; 3) 3%/1mm TH=50%**. Dynamic measurements with deliberately **simulated errors** were also taken (RTS switched off or sub-optimal coverage of the respiratory correlation model ~70%).
- The **DQA plans of 6 clinical patients** were delivered in different dynamic conditions, to give a total of 19 cases. The measured and planned dose distributions were evaluated with the same **γ-index criteria** used in step 1 and the measured **PinPoint doses** were compared with the planned mean doses in the sensitive volume of the chamber. The test was considered to have been passed when the 3 γ analysis criteria had a **GP>90%** or at least 2 criteria had a GP>90% and the PinPoint dose difference (**ΔD**) was **<5.0%**.

RESULTS AND DISCUSSION

- Comparison between the planned and the correctly delivered dose distributions confirmed the **dosimetric accuracy of the RTS for simple plans**. Student's paired t-tests were performed and no statistically significant differences were observed between the static and dynamic cases (p=0.41 for 3%/3mm criteria, p=0.62 for 2%/2mm criteria and p=0.76 for 3%/1mm criteria). The multi-criteria gamma analysis was able to **detect the simulated errors** (GP<70% with DTA=1mm), proving the robustness of the analysis method.
- All of the **DQA clinical plans passed the tests**, both in static and dynamic conditions. Student's paired t-tests were performed and no statistically significant differences were observed between the static and dynamic cases, confirming the **high degree of accuracy** of the Synchrony RTS (p=0.69 for 3%/3mm criteria, p=0.49 for 2%/2mm criteria, p=0.63 for 3%/1mm criteria and p=0.64 for ΔD). The mean GP (±σ) and the mean ΔD (±σ) are summarized in the Table 1:

	<GP> (%)			<ΔD> (%)
	3%/3mm	2%/2mm	3%/1mm	
Static cases	96.1 ± 4.5	98.8 ± 1.3	98.1 ± 2.2	2.7 ± 2.0
Dynamic cases	95.1 ± 6.1	98.4 ± 1.7	97.6 ± 2.4	3.1 ± 1.8

Tab. 1. Comparison between the mean gamma passing rates and the mean PinPoint dose differences for static and dynamic cases created for delivery quality assurance on patient plans.

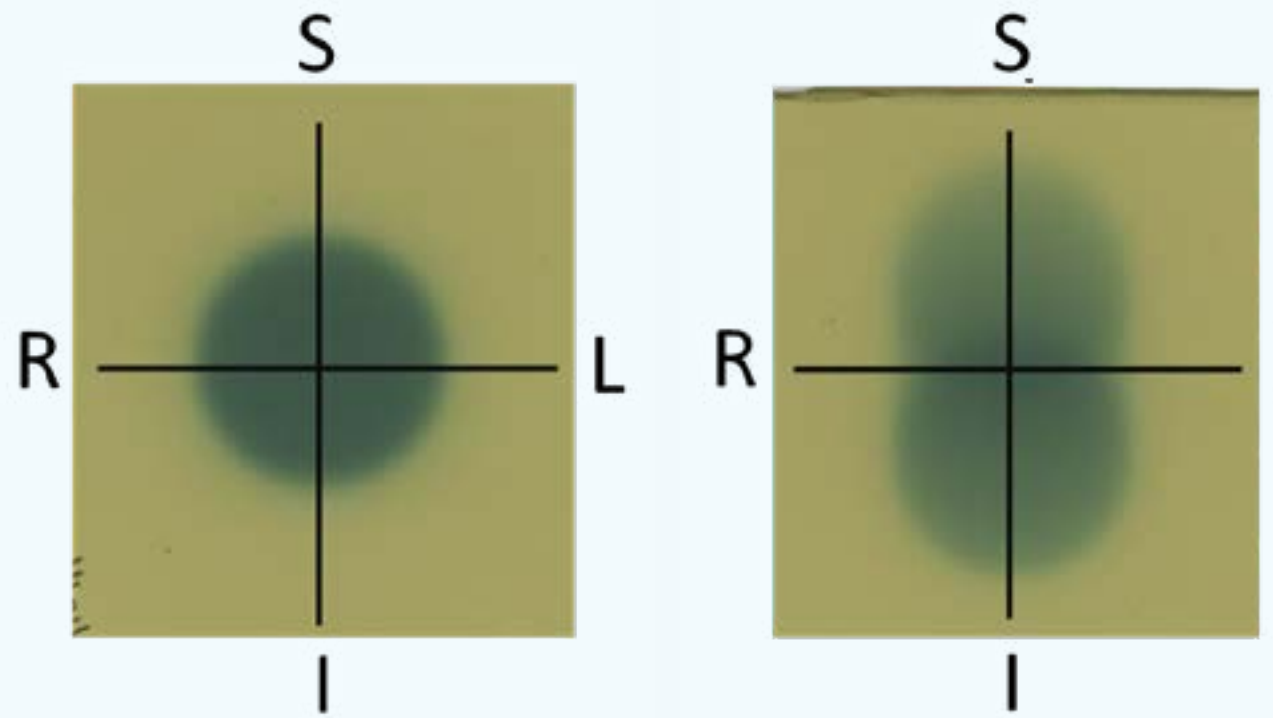


Fig. 2. Dose distributions for the 30 mm fixed collimator (sinusoidal breathing pattern, period=4s, amplitude=28mm). On the left: Synchrony switched on. On the right: Synchrony switched off.

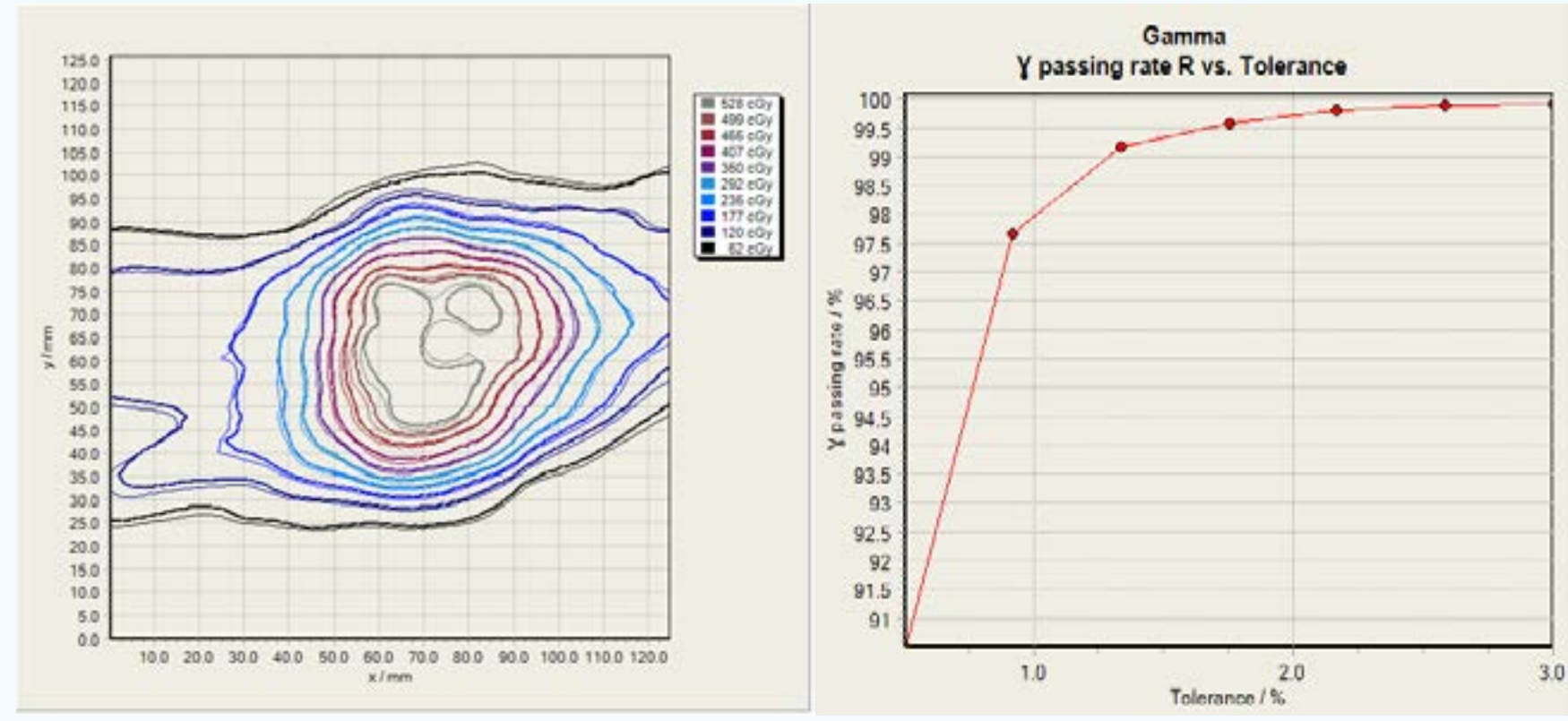


Fig. 3. Comparison of planned (thick lines) and delivered (thin lines) isodose maps of a routine plan (on the left). Gamma passing rate vs tolerance for the 2mm distance-to-agreement criterion (on the right).

CONCLUSIONS

The method presented confirms the fact that the RTS, if used properly, is able to **treat a moving target with great accuracy**. Our pre-treatment **patient-specific DQA method was robust**, combining PinPoint dose measurements and an evaluation of dose distributions with EBT3 films. However, a detailed study of each case is needed, especially when one acceptance criterion does not satisfy the tolerance level.

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