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Original article

Detecting anomalies in a deliberately biased tomotherapy plan: Comparison of two patient-specific quality assurance processes involving ArcCHECK® and Gafchromic® EBT3 films

suppl. Informations

Détection d'anomalies dans un plan de tomothérapie volontairement biaisé : comparaison de deux processus de contrôle qualité impliquant l'ArcCHECK® et les films Gafchromic® EBT3

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ABSTRACT

Purpose. – This work proposes a comparative evaluation of two of our patient-specific quality assurance processes involving ArcCHECK® (Sun Nuclear) and Gafchromic® EBT3 films (Ashland) in order to determine which detector is able to most effectively detect an anomaly in a deliberately biased tomotherapy plan.

Material and methods. – A complex clinical head and neck tomotherapy plan was deliberately biased by introducing six errors: multileaf collimator leaf positional errors by leaving one and two central leafs closed during the whole treatment, initial radiation angle errors (+0.5° and +1.0°) and multileaf collimator leafs opening time errors (+0.5% and +1.0%). For each error-induced plan, comparison of ArcCHECK® with Gafchromic® EBT3 films (20.3 × 25.4 cm²) was performed through two methods: a dose matrices subtraction study and a gamma index analysis.

Results. – The dose matrices subtraction study shows that our ArcCHECK® processing is able to detect all the six induced errors contrary to the one using films, which are only able to detect the two biases involving multileaf collimator leaf positional errors. The gamma index analysis confirms the previous method, since it shows all six errors induced in the reference plan seem to be widely detected with ArcCHECK® with the more restrictive 1%/1 mm gamma criterion, whereas films may only be able to detect biases in relation to multileaf collimator leaf positional errors. It also shows the common 3%/3 mm gamma criterion does not allow deciding between both detectors in the detection of the six induced biases.

Conclusion. – Both comparative methods showed ArcCHECK® processing is more suitable to detect the six errors introduced in the reference treatment plan.

Mots clés :
Tomothérapie
DQA
ArcCHECK
Films Gafchromic EBT3

RÉSUMÉ

Objectif de l'étude. – Cette étude est une évaluation comparative de deux de nos processus de contrôle qualité de plans de tomothérapie, impliquant l'ArcCHECK® (Sun Nuclear), ainsi que les films Gafchromic® EBT3 (Ashland). L'objectif de cette étude était de déterminer lequel de ces processus permet de déceler avec la plus grande précision une anomalie dans un plan de tomothérapie volontairement biaisé.

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Matériel et méthodes. – Un plan de tomothérapie de la sphère ORL a intentionnellement été biaisé en introduisant six erreurs : sur la position des lames en laissant une, puis deux lames centrales fermées durant la totalité du traitement, sur l'angle initial d'irradiation (+0,5° et +1,0°), ainsi que sur le temps d'ouverture des lames (+0,5 % et +1,0 %). Pour chaque plan biaisé, une comparaison entre l'ArcCHECK® et les films Gafchromic EBT3® a été réalisée à l'aide de deux méthodes : par soustraction de matrices de dose ainsi qu'à l'aide d'une analyse gamma.

Résultats. – L'étude par soustraction de matrices de dose a permis de montrer que notre processus utilisant l'ArcCHECK® était capable de détecter l'ensemble des six erreurs étudiées, contrairement au processus utilisant les films radiochromiques, qui ont uniquement permis la détection des deux erreurs liées à la position des lames. L'analyse gamma a confirmé ces résultats, puisque les six erreurs introduites dans le plan de traitement semblaient être détectées lors du contrôle avant le traitement avec l'ArcCHECK® lorsque le critère gamma de 1 %/1 mm était utilisé, tandis que le film Gafchromic® EBT3 ne détectait que les deux biais relatifs à la position des lames. Cette deuxième méthode a également permis de mettre en évidence que le critère gamma de référence de 3 %/3 mm ne permettait pas de départager les deux détecteurs quant à leur capacité à déceler les six erreurs introduites dans le plan de traitement étudié.

Conclusion. – Les deux méthodes de comparaison ont montré que le processus mettant en jeu l'ArcCHECK® était le plus adapté pour détecter les six erreurs introduites dans le plan de traitement étudié.

1. Introduction

The tomotherapy system is an intensity-modulated radiation therapy (IMRT) technique combining a linear accelerator mounted on a rotating ring gantry with a binary multileaf collimator device. A 6MV photon beam radiation is delivered constantly while the couch is moving into the gantry with a helical pattern [1,2]. The high number of degrees of freedom proposed by this delivery system (continuous motion of the linear accelerator and the treatment couch and variation of leaves position) allows a high degree of dose modulation in treatment plans. The complexity of helical tomotherapy technique involves a great potential for delivering errors. Therefore, patient-specific quality assurance (or delivery quality assurance) is required to ensure accurate dose delivery to the patients, detecting possible mismatches between the calculated dose by the treatment planning system and the dose actually delivered by the treatment machines [3–5].

Films inserted in a Cheese phantom (RMI 467, Gammex MRI) is a default methodology of Tomotherapy quality assurance verification widely used to validate the planar dose distribution with overlaying phantom plans [6,7]. Recently, radiochromic films succeeded radiographic films owing to their simplicity without chemical processors [8]. Their use for routine evaluation of patient-specific helical tomotherapy plans is time and resource consuming, requiring a postexposure waiting period before steps of scan, dose conversion and analyse using the common method of the gamma index calculation [9]. As with other IMRT techniques, there is a large interest in using electronic array detectors because they provide almost instantaneous absolute dose distribution. Two-dimensional detector arrays, such as MapCHECK (Sun Nuclear), Matrixx (IBA) and Seven29 (PTW) are used to validate planar dose distributions in standard IMRT [10–16]. Although these 2D detectors have been successfully used for Tomotherapy delivery quality assurance, they have some limitation for rotational-volumetric techniques in general [10,17,18]. Indeed, the 2D dose distribution information available when the beam incidence is perpendicular to the detector plane is continuously reduced to 1D as the beam angle approaches 90° [19]. More advanced 3D detectors, such as the Delta4 (ScandiDos), Octavius (PTW) or ArcCHECK (SunNuclear) have been developed for volumetric-modulated arc therapy (VMAT) and helical tomotherapy [20–24].

In our centre, tomotherapy patient-specific delivery quality assurance checks are performed with a Gafchromic® EBT3 film inserted in the Cheese phantom. In addition to its shape suitable for rotational patient-specific quality assurance, the ArcCHECK® detector can streamline the delivery quality assurance process because the gamma analysis is directly performed after treatment delivery. Delivery quality assurance process contains noticeably less steps than the one used with radiochromic films. The aim of this study is to compare two patient-specific quality assurance processes involving ArcCHECK® and Gafchromic EBT3 films, in order to determine which detector is able to most effectively detect an anomaly in a deliberately biased tomotherapy treatment plan. To achieve that, two comparison methods were used: a dose matrices subtraction study and a gamma index analysis.

2. Material and methods

2.1. Detectors

The two detectors used in this study were the ArcCHECK® and the Gafchromic® EBT3 films.

Measurements performed with Gafchromic® $20.3 \times 25.4\,cm^2$ EBT3 film sheets from the same batch (S/N 03311403) were achieved in a Cheese phantom. Films were placed horizontally in the phantom (film plan and table plan were parallels) with a landscape orientation (perpendicular to the direction of the table movement). The orientation of the film was consistent for all measurements and each film was marked thanks to green lasers to allow consistency in setup. An A1SL ionization chamber (Exradin) was inserted at the centre of the phantom allowing an accurate repositioning. All radiochromic films were processed and analysed around 24 h after exposure. They were scanned using the Expression 10 000 XL (Epson) scanner at a resolution of 72 dpi (this represents a sample of just over 400,000 pixels per film) and were then converted into dose using multi-channel dosimetry method [25]. A calibration curve for the Gafchromic® film batch was determined for a range of doses between 0 and 300 cGy. The homogeneity of the scanner's response was equal to 1.7% on the whole area of the film after dose conversion. Landmarks in the scanner allow the positioning of films in the area where the response of the scanner is the most homogeneous. All films were placed in this scanner area. The global gamma index analysis was performed with the DQA Station (Accuray) v.5.0.2 software. To extract dose values from each pixel, DoseLab Pro™ (Mobius) v.6.4 and MATLAB (MathWorks) v.R2013b software were used.

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