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The role of AGFA high-energy CR in the calibration and quality control of multileaf collimators (MLC)

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Abstract Linear accelerators equipped with multileaf collimators (MLC) are becoming more common and are widely used in the intensity-modulated radiotherapy (IMRT). There is an imperative need to ensure the commissioning specification of the linear accelerators for the sake of quality assurance (QA) and quality control (QC). This paper is aimed to investigate the role of AGFA high-energy CR (Computed Radiography) in calibrating dynamic multileaf collimators and evaluating the accuracy of the leaf position. The result shows that AGFA high-energy CR can easily and conveniently be used to calibrate MLC and verify its position. Hence, the application of AGFA high-energy CR is proved to be an accurate and time-saving method for routine MLC QC, especially when MLC calibration adjustments are required.

Key words High-energy CR, MLC calibration, Quality control

CLC numbers R730.55, R815

1 Introduction

Intensity-modulated radiotherapy (IMRT) plans based on DVH (Dose Volume Histogram) data is more frequently chosen by experienced radiation oncologists than 3D conformal plans. The advantages of IMRT plans include both improved PTV (Plan Target Volume) coverage and improved sparing of critical organs. MLC is the premier device for IMRT and MLC conformal accuracy is the key point for IMRT implementation. As a device that determines the final therapeutic effect, high accuracy MLC is obligatory for delivering the prescribed dose with IMRT. QA & QC (quality assurance and quality control) of MLC, a major task for medical physicists, is a prerequisite to IMRT for actual patient treatment.

MLCs commercially available are used by radiation oncology department of many hospitals in China, whereas many hospitals in other countries use well engineered MLCs that allow simple blocking, conformal therapy or ultimately intensity modulated treatment.[1-5] However, attention to commissioning an MLC is not well warranted in many radiation facilities. There are many different methods to fulfill the task, but the process for most of current methods is quite complicated and expensive apparatus are needed to finish the job.

In our department, leaf calibration for MLC verification was initially done with films. Now, AGFA high- energy computed radiography (CR), with its accuracy and reliability being tested, are used for daily, weekly and monthly quality control of the MLC. AGFA high-energy CR provides two-dimension data of high resolution, and requires virtually no time for set-up or post-processing to obtain useful data. In this paper, we present the development of a fast, accurate and 2-dimensional method to fulfill the QA and QC of MLC with AGFA high-energy CR.

2 Materials and methods

2.1 General materials

AGFA CR 25.0 scanner, AGFA CR QS 3.0 workstation, CR QS radiotherapy software and AGFA MV

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high-energy imaging plates (CR RT 1.0 for <10cGy low dose applications and CR RT 1.5 for 10~400cGy high dose applications) were from AGFA Corp., Germany. LANTIS network, Siemens ONCOR LINAC (with 29 pairs of leaves), and Siemens EPACT (Efficient Positioning and Calibration Tool) MLC calibration software were from Siemens Corp., Germany, as shown in Fig.1. CMS XIO TPS software (XIO 4.3.0) was provided by Computer Medical System Inc. USA.

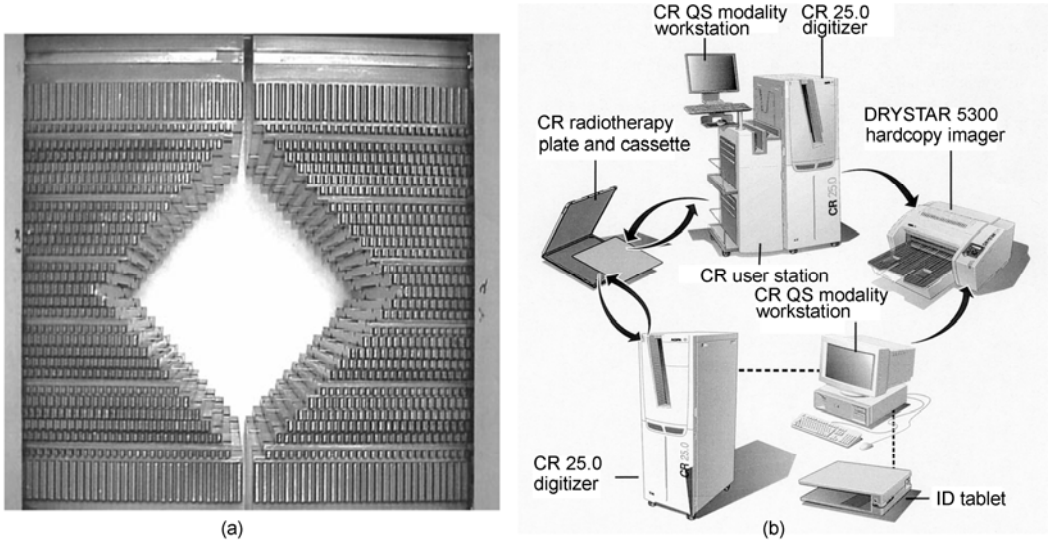

Fig.1 (a) MLC leaf configuration of the Siemens ONCOR linac, (b) CR high-energy radiotherapy system.

2.2 The MLC

The Siemens ONCOR LINAC MLC consists of 29 pairs of leaves, with a projected width at isocenter of 1 cm, and two pairs of 6.5 cm wide outer leaves. The leaves are double focused and the leaf-ends are straight. Each leaf is moved by an independent motor and can travel 10 cm across the beam central axis.

2.3 Leaf calibration with bar strip

A light field provides a procedure of first line checking for leaf and collimator positioning. This is important for keeping the X-ray field size and checking frequencies (a more difficult task) to a reasonable level.[5] Placing a sheet of paper printed with 1 mm grids on the treatment couch, asymmetries at the isocenter can be readily detected when defining a rectangular field. However, in relation to the MLC the limitations of the light field should be mentioned.[6] So the accuracy and reproducibility of leaf calibration is evaluated with CR.

An MLC field consisting of five 1cm×20cm and two MU segments was used to study the leaf positioning accuracy (Fig.2a). The segments were delivered sequentially, by moving the leaves from left (-*x*) to right (+*x*). The segments were centered at -10.5, -5.5, -0.5, 5.5, and 10.5 cm at the *x*-axis (direction of leaf motion). A low dose imaging plate (IP) was placed on the treatment couch, and the couch height was adjusted to an SID (source-to-the-IP distance) of 100cm. The gantry angle was adapted to 0°. All measurements were performed using 6 MV X-ray beams. Data sets of the IP were acquired by the scanner, and analyzed with CR QS radiotherapy software. The results were shown in Fig.2b. Uniform intensity bar strips were generated by the CMS TPS software and were delivered by the MLC.

The short-term and long-term reproducibility of the leaf gap widths were investigated with the procedure mentioned above. The short-term reproducibility is possible variations in leaf positions during a given treatment session. It is assessed from repeated (five times) deliveries of the MLC field and CR image acquisition in a time interval of less than a minute. The long-term reproducibility describes variations in the realized leaf gap widths, as compared to a prescribed width of 1cm over a period of 10 months. It was derived from 40 CR measurements during the period of time. The methods to derive leaf gap widths from the acquired images are described in the following section.

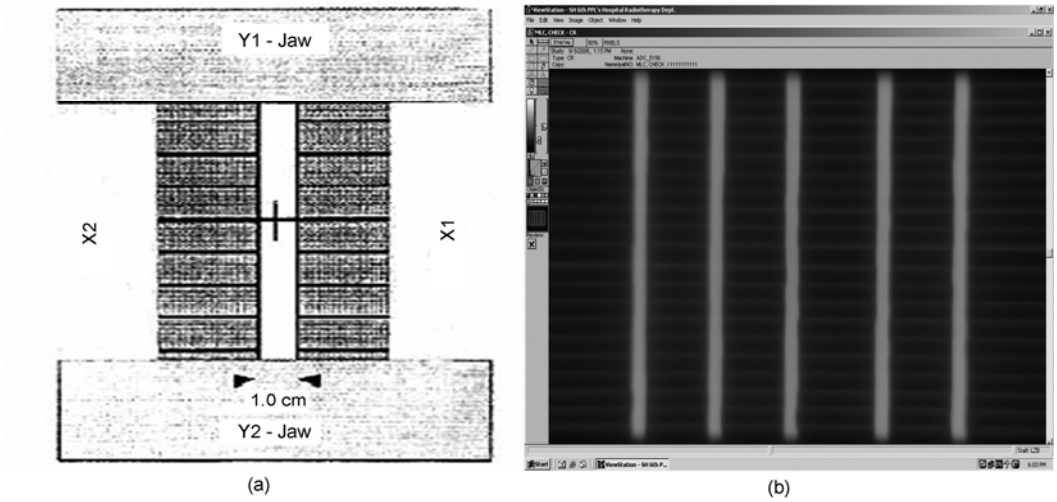

Fig.2 Geometric set-up for assessing the MLC carriage sag. Each leaf pair is programmed to deliver dose with a gap of 1 cm in each movement of about 5 cm. (a) The leaf configuration, (b) The results.

2.4 Leaf calibration with special segments series

A high dose IP was placed on the couch, and the SID and gantry angle were adjusted to100cm and 0°, respectively. Radiation field was irradiated with 6 MV X-ray beams. MLC series were designed by CMS TPS and would be transferred from LANTIS server to radiotherapist workstation. Data sets would be gathered from AGFA IP template after radiation was delivered and were analyzed with CR QS radiotherapy software. If black (or white) lines appear in the images (Fig.3 a), the location and velocity of MLC leaves were calibrated with MLC calibration software EPACT (Fig.3 b).

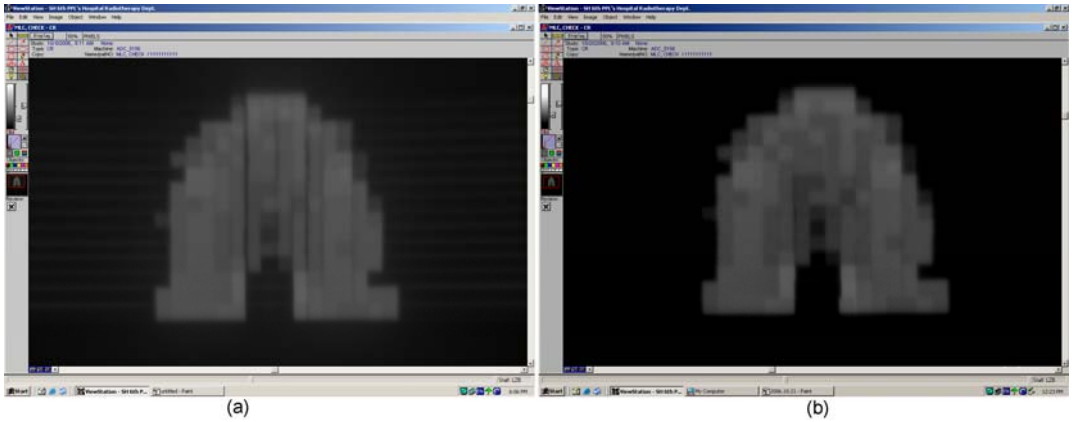

Fig.3 Special series designed to check connectivity of the segments. (a) before calibration; (b) after calibration, the black lines disappeared after the calibration.

3 Results and discussion

CR image has high spatial resolution, but it is not consistent with the required precision by naked eyes. This is a problem similar to QA of the MLC with films.[7,8] However, software can be applied to analyze the digital CR images and improve the calibration accuracy. The image grade at the edge of irradiation field is different from the other areas and the boundary of MLC leaves can be detected with image analysis software, in comparison with the planned radiation field boundary, and the MLC leaf location can be checked. Edge-detection algorithm is used frequently in this regards.

(1) In this paper, the positional error of the MLC was evaluated using bar strip of uniform intensity, as shown in Fig.2(b). If the intensity bar strips did not have a straight edge, the leaf positions had to be recalibrated as illustrated in Fig.4.

(2) Validations on accuracy of the leaf location

and the segment series and connectivity of the MLC, and assessment of the dose distribution for every field, can be done by high energy CR.[9] The spherical hyper-block or hypo-block of the MLC leaf image in Fig.3(a) show two black lines. In Fig.3 (b), however, the black line disappeared after calibration. In monthly QA of MLC last year, we found that two mis-positioning problems of the MLC leaves, which would not be detected by conventional method of bar strip of uniform intensity.

(3) Fig.5 shows the standard deviations of the leaf position measurements from the prescribed position. The results for beam segments centred at -10.5, -5.5, -0.5, 5.5, and 10.5 cm, respectively. The error bars represent long-term (10 months) reproducibility in x_1 (a) and x_2 (b) direction over the entire period of the measurements at the center position -0.5cm. Apart from one leaf the position errors were less than 1 mm. Similar results were found for other segments. For static beam treatments, a leaf positioning accuracy with 1~2 mm standard deviation is generally considered acceptable in the clinic[10], though Siemens guarantees an accuracy of leaf positioning within ±1 mm.

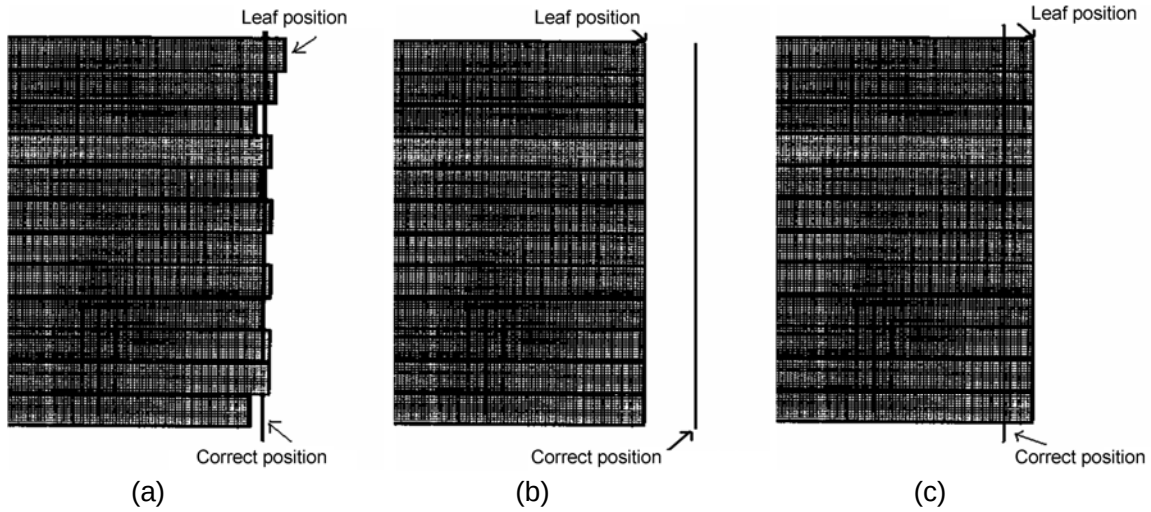

Fig.4 Relationship between the leaf bank calibration and individual leaf calibration. (a) Some leaves were not at the correct position and the intensity bar strips did not have a straight edge. (b) and (c) The intensity bar strips have a straight edge, but all the leaves were not at the correct position.

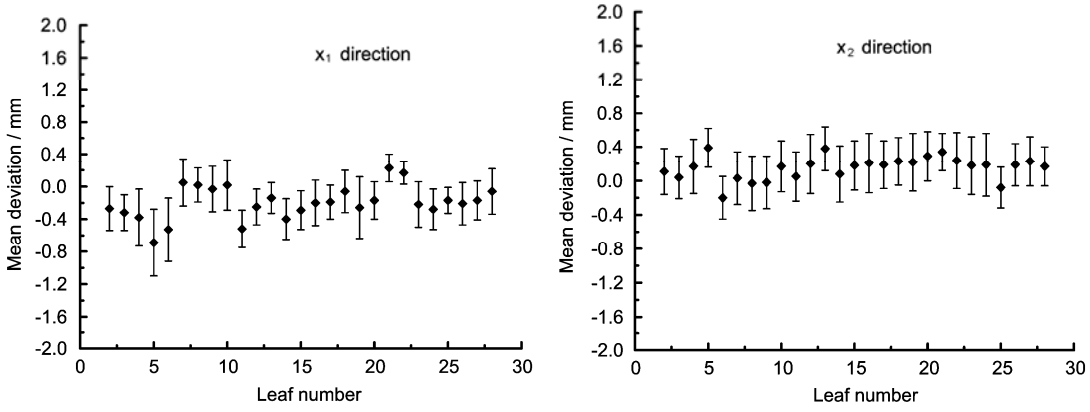

Fig.5 Standard deviations of the leaf position measurements from the prescribed position. The results for beam segments centred at -10.5, -5.5, -0.5, 5.5, and 10.5 cm, respectively. The error bars represent long-term (10 months) reproducibility in x_1 (a) and x_2 (b) direction over the entire period of the measurements at the center position -0.5cm.

X-ray film and EPID (Electronic Portal Image Device) are methods widely used in China currently for QA of the MLC. However, developing and fixing X-ray films must be done in a darkroom, despite the fact that they have small energy range, unchangeable imaging phase and high expose rate. Being able to image just the radiation field, EPID can only be used in one accelerator due to the small FOV and low resolution of the newly equipped linac. In contrast to X-ray film and EPID, CR offers post-processing image en-

hancement, leading to higher contrast images within radiotherapy application areas where the radiographic imaging is used. CR is also a cost-efficient choice, as this requests no films, chemicals, dark room and storage space, though the technique is complicated by a number of image quality-affecting factors.

4 Conclusions

(1) The high-energy CR response is similar to a film but CR set up is easier, for all data can be acquired in a few minutes, the real-time response and the fast data handling greatly reduce the time dedicated to the measurements during acceptance and quality control procedures. Compared to routine X-ray film, the high-energy CR has the advantage with no need for developing and fixing film in darkrooms, and it can also avoid renewing imaging due to the unsuitable imaging parameters of X-ray film in great degree.[11-13]

(2) CR is the easiest digital imaging technique when the old machine can not equip the EPID or there are no enough funds to equip the EPID on the all machines; CR can reduce the time for the process of MLC quality assurance and improve efficiency.

(3) The results of our study suggest that, after a proper calibration, a 1 mm tolerance level can be achieved and may be used as a standard value for the verification of leaf positions. The positioning accuracy verification of MLC is an important part of the routine quality assurance package for IMRT treatments.

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