Automatic Multileaf Collimation Quality Assurance for IMRT using Electronic Portal Imaging

Ho-Sang Jin[a], Jason W. Sohn[b], and Tae-Suk Suh[a]

[a]Dept. of Biomedical Engineering, The Catholic University of Korea, Seoul,137-701, Korea, [b]Dept. of Radiation Oncology, Washington University in St. Louis, St. Louis, MO, 63110, USA
e-mail: hsjin@catholic.ac.kr

ABSTRACT

More complex radiotherapy techniques using multileaf collimation(MLC) such as intensity-modulated radiation therapy(IMRT) has been increasing the significance of verification of leaf position and motion. Due to the reliability and robustness, quality assurance(QA) of MLC is usually performed with portal films. However, the advantage of ease of use and capability of providing digital data of electronic portal imaging devices(EPIDs) have attracted many attentions as alternatives of films for routine quality assurance in spite of the concerns about their clinical feasibility, efficacy, and the cost to benefit ratio. In our work, the method of routine QA of MLC using electronic portal imaging(EPI) was developed. The verification of availability of EPI images for routine QA was performed by comparison with those of the portal films which were simultaneously obtained when radiation was delivered and known prescription input to MLC controller. Specially designed test patterns of dynamic MLC were applied to image acquisition. Quantitative off-line analysis using edge detection algorithm enhanced the verification procedure in addition to on-line qualitative visual assessment. In conclusion, the EPI is available enough for routine QA with the accuracy of portal films.

Keywords: Electronic portal imaging, Multileaf collimation, quality assurance

1. INTRODUCTION

One of the vital parts of intensity modulated radiation therapy(IMRT) using multileaf collimation(MLC) is the reliability of the motion and position of MLC during the treatment. To meet this requirement, quality assurance(QA) of MLC must be implemented routinely. Portal films are the most common method for the QA of MLC in the conventional clinical sites. But the QA using portal films has several limitations despite their reliability and robustness. It is usually visual assessment on dose delivery after development and need to be digitized for quantitative assessment. Moreover it is not efficient because it takes time for film development and needs storages for the films. Electronic portal imaging device(EPID) has attracted many concerns as a realistic alternative of portal films to overcome their drawbacks. In our study, two kinds of test patterns which were transferred to dynamic MLC controller were introduced to verify the feasibility of EPI for the routine QA as the substitution of portal films. The objectives of our study were (1) to prove the relationship between prescription of dynamic MLC and images of portal films, (2) to compare this result with that of the same method using EPID, and (3) finally, to verify the availability of EPI for routine QA.

2. METHOD AND MATERIALS

2.1. Equipment and Materials

Radiation delivery was implemented with Varian Clinac 2100C(Varain Associates Inc., Oncology Systems, Palo Alto, CA) equipped with 80 multileaf collimators. Kodak V film(Eastman Kodak Co., Rochester, USA) for film study and EPID using matrix liquid-filled ion chambers for the EPI study were used.

2.2. Test Patterns of dynamic MLC

Specially designed two kinds of movement patterns of MCL leaves were applied to the MLC controller. Each pattern was composed of 18 MLC segments during the radiation exposure. In the first pattern(test pattern 1), all the leaf pairs are moved from left to right and only 5 segments have radiation delivery for the most part with tip distance of 1mm between leading leaves(Leaf A) and trailing ones(Leaf B). The other pattern(test pattern 2) was introduced to find out the relationship between the tip distance on images of films and EPI and that of prescription. So it has several tip distances of 2, 3, and 4mm in different leaf pairs. Field size of exposure was $15\times15cm^2$ which contained 14 valid leaf pairs for the study in all cases. Image acquisition was repeated 5 times for each pattern.

2.3. Qualitative and Quantitative Analysis Method

EPI image was simultaneously acquired with that of portal film during radiation exposure and the former was transformed to be registered with the latter using point matching method, one of rigid-body transformations(Fig. 1). Two corner points on each image was selected as reference points for matching after edge detection.

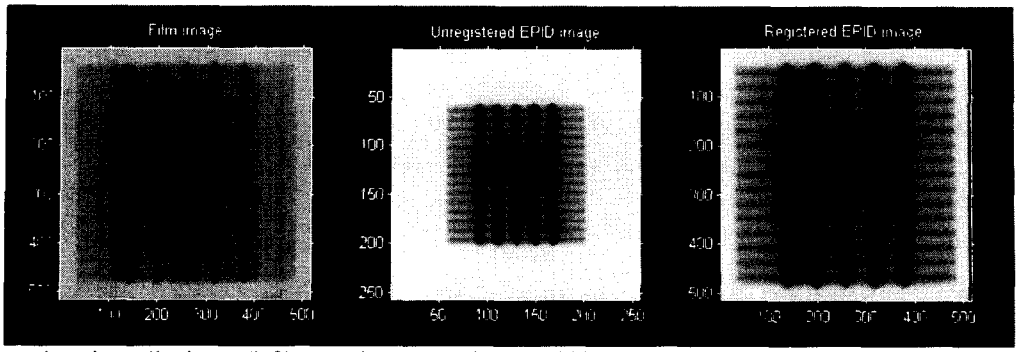

Fig. 1. Image registration. Film image(left), unregistered EPI image(middle) and registered EPI image(right)

Qualitative visual inspection is carried out by examining overall uniformity on intensity of film and EPI images which means proper dose delivery, that is, movement of the MLC leaves and vertical arrangement of leaf tip positions on the images. For better inspection, 3 dimensional dose profile was developed(Fig. 2).

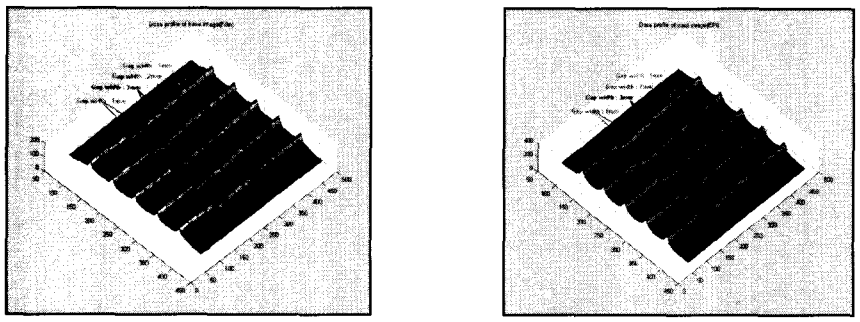

Fig. 2. 3D dose profile(Test Pattern 2). Film(left) and EPI(right) images.

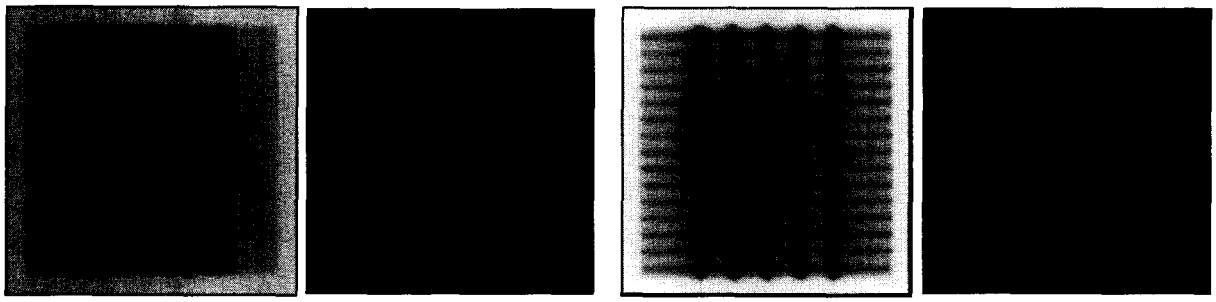

Fig. 3. Edge detection of film image(left) and EPI image(right) (Images of test pattern 2).

For quantitative analysis, the film images were digitally scanned and both the film and EPI image were followed by edge detection(Fig. 3). The detected leaf edges on binary images were used for calculating the gap width between two leaves and it was compared with the prescribed tip distance of leaves. Deviation of center positions between two leaves on the images from the prescription were also examined for the verification of MLC leaves position. Finally, the availability of EPI for routine QA was verified by comparison with the images of portal films.

3. RESULTS

3.1. Comparison of gap width

The maximum gradient in intensity in the penumbra region of a portal image corresponds to the 50% isodose curve and

hence the dosimetric field edge[5]. Correspondingly, our study shows that the distance between the maximum gradients in intensity is equivalent to full width at half maximum (FWHM) in the dose profile(Fig. 4). Basically FWHMs were utilized as references of gap width on portal images.

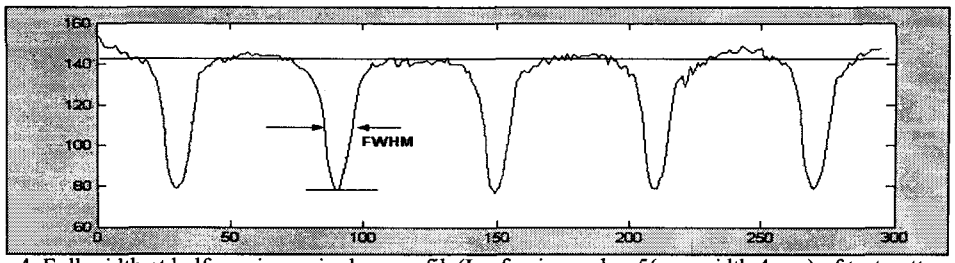

Fig. 4. Full width at half maximum in dose profile(Leaf pair number 5(gap width:4mm) of test pattern 2)

Table 1. Comaparison between prescription and FWHM of portal images.

Prescribed Gap Width(mm)	Mean FWHM of Film image(mm)	Mean FWHM of EPI image(mm)
1	3.0	3.1
2	3.5	3.8
3	4.5	4.8
4	5.5	5.6

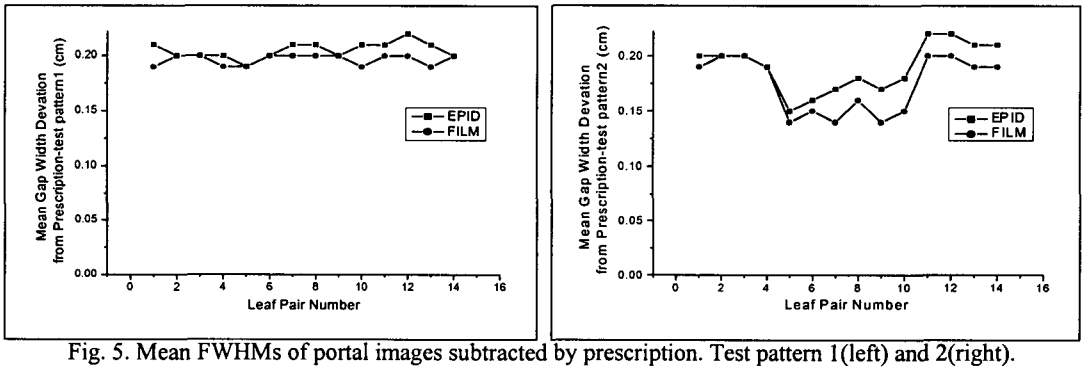

Fig. 5. Mean FWHMs of portal images subtracted by prescription. Test pattern 1(left) and 2(right).

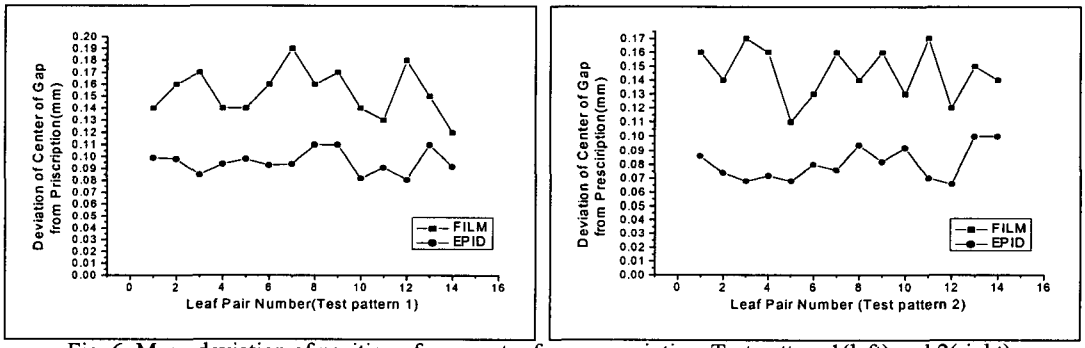

Fig. 6. Mean deviation of position of gap center from prescription. Test pattern 1(left) and 2(right).

The FWHMs are longer than prescribed gap width (Table 1). And the FWHM of EPI images is slightly longer than that of images of portal films. Fig. 5. shows mean deviations of FWHM of portal images subtracted by the prescribed value. The differences between film and EPI images were 0.091±0.068(mean value±1SD) mm for the test pattern 1 and 0.15±0.11mm for the test pattern 2.

3.2. Comparison of gap center

Center position of gap combined with comparison of gap width is a good indicator for verification of MLC leaf position. This comparison is crucial since the center of gap corresponds to hot spot in dose profile. The mean deviations of gap

centers were 0.15±0.020mm in film images and 0.088±0.013mm in EPI images. These deviations are equivalent to the order of a half or a third pixel of image. It indicates that MLC leaf position was in the right prescribed position. The study with EPI presented better results than that with film. The results shows that EPI is available enough for routine QA of MLC with the same or better accuracy of portal films.

4. DISCUSSION

For the successful verification, there must be exact image registration between the two image sets. There were registration errors approximately within 2 pixels (~0.66mm) after registration. These errors were minimized by image translation by overall mean deviation of distance of gap center. Due to the limitation of EPID with ion chamber, the image acquisition of EPI should be implemented with adjusted contrast level of the image. The edge detection algorithm is very susceptible to noise on image. Many noises of film images are introduced during the process of development and digitization with a film scanner. These noises should be reduced for better results. Therefore EPI shows better results in the process of edge detection (Fig. 3). The FWHM of portal images approximately has the relationship of a linear equation with prescription. The gap width by edge detection of portal images can be estimated into real prescription by the equation (Fig. 7.).

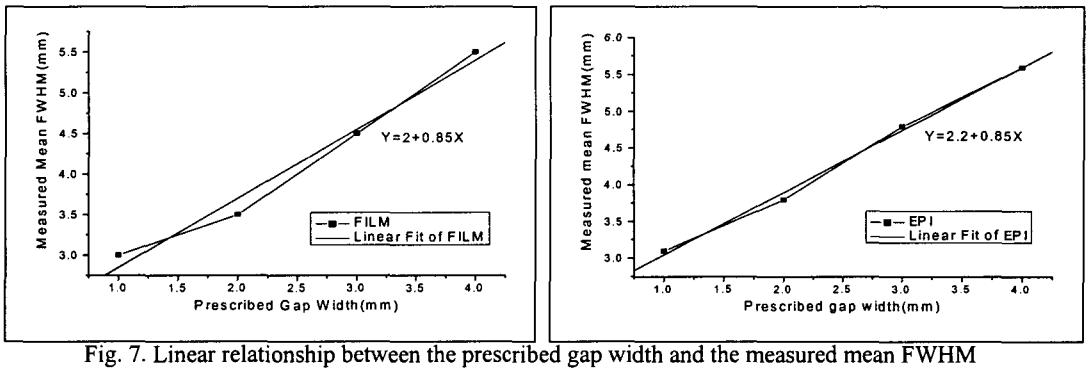

Fig. 7. Linear relationship between the prescribed gap width and the measured mean FWHM

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