• Technology and Methods •

Quality control for multileaf collimator leaf position accuracy using amorphous silicon electronic portal imaging devices

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[Abstract] Background and Objective: The multi-leaf collimator (MLC) leaf position deviation of the linear accelerator (LINAC) can result in dose distribution errors during intensity modulated radiotherapy (IMRT), which would cause treatment failure and serious injury to the patients. This study was to develop a simple method to control the MLC leaf position accuracy. Methods: Elekta LINAC, Elekta iView aSi electronic portal imaging devices (EPIDs) and an 8MV photon beam were used. A digital image designed by a treatment planning system (TPS) was acquired using the EPIDs and was analyzed to compute the MLC leaf position coordinates. The position error was thus obtained by comparing the coordinates in the image with those in the TPS DicomRT file, which was used to quickly adjust the MLC leaf position. Result: The leaf deviation of leaf position accuracy was kept less than 1 mm. Conclusion: Quality control for MLC leaf position accuracy using EPIDs is simple and adequate.

Key words: multi-Leaf Collimator, position accuracy, Electronic Portal Imaging Devices, quality control

Static intensity modulated radiation therapy (IMRT) technology using multi-leaf collimator (MLC) was introduced into clinical in the recent decade. The IMRT technology can produce steep dos distribution which can increase the dose to the tumor and spare more surrounding normal tissues. On the other hand, the dose gradient distribution error can cause serious injury to the patients. Thus the quality control (QC) of the linear accelerator (LINAC) is very necessary, which can assure the LINAC to deliver the treatment plan accurately. One important QC item is the QC for MLC position accuracy. The dose gradient distribution error is dominated by MLC position accuracy. Therefore the QC for MLC position accuracy is more and more important. Woo etc al.1 revealed that the leaf end position accuracy can vary the signal to ion chamber up to 13%. Parent etc al.2 pointed out the system error of MLC position accuracy can be reduced and can be less than 1.0mm using radiographic film and electronic portal imaging devices (EPID). Ju et al.3 measured the MLC (Elekta LINAC) position accuracy using a two-dimensional ion chamber. The measurement size of MLC is 27cm x 27cm, and the MLC was adjusted after the measurement. The MLC position accuracy can meet the clinical demand. In this paper, a series field pattern was
designed using the Pinnacle treatment plan system and acquired digital field image using EPIDs. Software which can process DICOM files and images based on the Matlab platform were used to process the QC procedure for the MLC position accuracy of Elekta LINAC.

**Materials and Methods**

**Linear accelerator.** Elekta LINAC was used in the measurement. The upper jaws (Y direction) were replaced by MLC and Backup combination. The lower jaws were the conventional jaws. There were 40 pairs of MLC and the leaf width was 1cm at the iso-center plane. The 8MV photon beam and 100 MU were used in the measurement at zero degree of gantry and collimator.

**EPIDs.** Elekta iView GT aSi flat EPIDs which was attached to the opposite side of gantry, and the distance between the source and EPIDs was 160cm, the real size of EPID was 41cm x 41cm, and the size was 26 cm x 26 cm at the iso-center plane. The digital image obtained by EPID is 1024 x 1024 and 16-bit grayscale image.

**Pinnacle 8.0 three-dimension treatment systems.** In pinnacle 8.0 TPS, a water phantom was used and a series of filed patterns was designed just like Fig. 1 (a). The minimal diamond field size is 2 cm x 2 cm, and the size was increased by step of 2 cm to the maximal field size of 20 cm x 20 cm. The field pattern in Fig. 1 (b) could compensate the disadvantage of the field pattern in Fig. 1 (a). The up and bottom leaf path are too small in Fig. 1 (a). All the field patterns in Fig. 1 can decrease the impact of backup.

**Matlab 6.5 software.** We developed a graphic user interface software which can process DICOM file and digital image based on Matlab (Fig. 2).

**Methods.** The treatment plan including the field pattern in Fig. 1 was send to Elekta LINAC and the local disk through DICOMRT protocol, the file in the local disk was read into analysis software to obtain the plan position coordinates of all leafs. Before acquiring the field image form EPIDs, a calibration square field of 10 cm x 10 cm was obtained from EPIDs which can get the resolution of EPIDs and the center of the image (x0, y0). All the designed fields keeping the EPIDs position were acquired that is the same center of the image center. The real leaf position coordinates were acquired from images through differential algorithm. The deviations between the plan leaf position in DICOM files and the real leaf position were obtained. Therefore the Offset value of the leaf can be adjusted by half according to the deviations. A series of diamond fields were measured and a compensated field (figure 1 (b)) was measured as well. The 40 pairs of leafs were measured and adjusted by means of moving EPIDs forward and backward.

![Figure 1](image1.png)  
*Figure 1  The BEV field shape for quality control*
**Edge detection algorithm.**
The digital images are 1024x1024x3 matrixes. The first step was to convert the digital images to two-dimensional gray scale image 1024x1024 and change the integer (0-255) gray value to double precision (0-1.0). In Fig. 3, the edge function is to describe the gray value range function. The maximum of change of gray value can be obtained by means of the difference for the edge function and the maximum is the edge of the gray scale image. The algorithms are as follows:

\[
\text{left}(n) = \min \left( \frac{\partial I(m, n)}{\partial m} \right) \tag{1}
\]

\[
\text{right}(n) = \max \left( \frac{\partial I(m, n)}{\partial m} \right) \tag{2}
\]

In equations (1) and (2), \(I(m, n)\) is the gray value matrix of the image, \(\text{left}(n)\) and \(\text{right}(n)\) are the left leaf position coordinate array and the right one. The difference is the process along the leaf movement direction and the minus value is the left leaf position and the max value is the right leaf position.

**Result**

After the measurement, the software analysis the leaf position accuracy and the calibration was performed. The resolution of the software and the EPIDs is 0.25mm, and can control the leaf position error of Elekta LINAC within 1mm (Fig. 4).

**Discussion**

In this paper a series of field patterns was designed in Pinnacle TPS, so that any field pattern can be used in the measurement. A QC must be performed to EPIDs before QC for MLC position accuracy in order to keep the image gray uniform to avoid the noise appeared after difference. In this work, a series of strange field patterns were designed to avoid the impact of backup jaw and consider the conventional measurement of calibration for the field size. A picket fence pattern was used in Baker et al.s study that was a bank of leafs moving from one side of the field to another side in the leaf.
movement direction usually by step of 2 cm, and every movement of an exposure was given to form picket fence pattern. Similarly, in this study, a series of diamond field pattern which formed the minimal 2 cm x 2 cm to 20 cm x 20 cm by step of 2 cm. At every field size, an exposure was given and a measurement was performed. This method can produce four picket fence patterns at four directions, like conventional field calibration. The advantage of the diamond field pattern is that compensation must be done as shown in Fig. 1(b). The max field size of EPIDs can be measured is 25 cm x 25 cm. The EPIDs should be moved along the GT direction, so that the measurements and adjustments for all leaves can be done. A differential algorithm was used to obtain every leaf position coordinate. The grayscale value distribution in penumbra is Gauss distribution. The max change of grayscale is the middle of the grayscale. Therefore, we used a differential algorithm to find the max value that was the max change of the grayscale. This method is simple and quick. A pixel error can appear in differential algorithm for digital images, so a correction must be performed later. At the same time, EPIDs can measure the MLC at different gantry angles to detect the impact of gravitation. From the measurement, the impact of gravitation can be disregarded. The deviation of MLC position error is made of the system error and stochastic error. The stochastic error can not be avoided. We tried to decrease the system error. In Fig. 4, the distribution of leaf positions are random and the region is $+0.5$ mm, which can meet the clinical demand. The collimator should be at 0 degree when the image is obtained. When the leaf width was 1 cm, the max half field size was 10 cm, the collimator angle must be within $+\arctan(0.05)=2.8$ degree theoretically and the error could be added was 0.175 mm. The added error was only 0.04 mm when the collimator angle was within $+0.5$ degree. The pinnacle resolution was 0.1 mm, so the real error was 0.1 mm. A lot of institutes have EPIDs and the EPIDs have been a advantage tool. In practice, the EPIDs can quickly perform QC for MLC position accuracy, and the error of MLC position can be kept less than 1 mm to meet the clinical demand.

References:


