EVALUATION METHODS FOR SPEED AND POSITIONING OF MULTILEAF COLLIMATOR LEAVES

Tadas DIDVALIS, Evelina JASELSKĖ, Antanas VAITKUS

MEDICAL PHYSICS IN THE BALTIC STATES KAUNAS, 2015
Introduction

Intensity modulated radiotherapy (IMRT) is a type of radiotherapy that has more precise dose distribution than other conventional radiotherapy types because dose intensity in the field is not homogenous. Dose distribution is modulated using multileaf collimator (MLC), which leaves move during irradiation.
Bai et al. (2013) study with intensity modulated radiation therapy plans, which were intended for the treatment of nasopharyngeal carcinoma, showed that 0.5 mm, 1 mm and 2 mm systematic MLC positioning errors caused dose deviations of 4.63%, 8.69% and 18.32%.

Mu et al. (2008) Examined that the ± 0.5 - 1 mm MLC systematic errors can cause an average of 4% of the dose deviations for ordinary IMRT plans and up to 8% dose deviations for complex plans.
Ranger et al. (2010) found that conventional IMRT plan verification methods can not detect systematic errors up to 1 mm, so "patient specific IMRT plans for quality control can not replace routine MLC system quality control."

Both the American Association of Physicists in Medicine and European Society for Radiotherapy and Oncology highlights multileaf collimator routine quality checks, of those the most important tasks is to assess the leaf positioning accuracy and speed stability.
Equipment

LINAC – Varian Clinac iX
Multileaf collimator – Varian Millenium MLC 120
Portal imaging device – Varian EPID aS1000
Dosimeter – SunNuclear MAPCHECK
Dosimetry film – Kodak X-Omat V
“Garden fence” test.

Intended to evaluate leaf positioning errors.

Pair of opposing leaves form seven 2 mm gaps.

Deviations can be evaluated visually or using image analysis methods.
Methods (2)  “Garden fence” test image analysis
“Speed” test.

Intended to evaluate stability of leaves travel speed.

Every other pair moves at speed $v_1$, others at $v_2$.

$v_1 = 2v_2$

Deviations can be evaluated visually or using image analysis methods.
Methods (4)  “Speed” test image analysis
Methods (5)  Calculation of errors

- In order to determine the influence of random errors in measurements, 5 identical “garden fence” test fields were irradiated. The results are presented in the following format:

\[ x \pm \frac{t_{p,n} S_x}{\sqrt{n}} \]

- In this paper, confidence probability \( P_{\text{int}} = 0.95 \), so Student coefficient \( t_{p,n} = 2.8 \). Standard deviation for gap measurements \( S_x = 0.028 \) mm. Error \( \Delta x = 0.035 \) mm.

- In "Speed" test measurements only the standard deviation was used. It was calculated after irradiation of 5 identical "speed" test fields. The standard deviation: \( S_x = 2 \) μGy
Workflow
Results (1)
“Garden fence” test

Largest measured gap deviation was 0.103mm ± 0.035 mm, P = 0.95. This deviation is 10.3% of permissible deviation which is 1mm. All other measured deviations were smaller than this.
Results (2)
Influence of interleaf transmission

Corelation coefficient $r = 0.45$. It means that corelation is positive and weak – interleaf transmission does influence measured gap but it is not the only factor.
Results from the film correlates with results from EPID. Also visual comparison of images obtained show that film image is not so clear and contrast is worse.
Results (4)

EPID and MAPCHECK

MapCHECK resolution is significantly worse than EPID. For this reason the results obtained with MapCHECK are not discussed.
It was not observed that leaves travel speed, gentry and the collimator position would have a significant impact on the size of measured deviations. The measured deviations were in the limits of random errors.
Recommended leaf speed deviation must be no more than 0.5 cm/s. Deviation this big would lead to dose profile deviations up to 10% if a pair would be moving at 2.5 cm/s. After estimating travel speed deviations from acquired images by eye and dose profiles by image analysis it was observed that these deviations were small, they were only hundredth of a percent.
Results (7)
DynaLog file analysis

They record the number of times during the irradiation beam was stopped because leaves were not in the position specified in the treatment plan. It can be in two instances:

1. If the plan requires leaf to travel faster than physical maximum speed (2.5 cm/s)
2. If because of systematic or random errors leaves can’t maintain their speed.

In this study the maximum leaf speed was 2.4 cm/s, so 1 case is unlikely. DynaLog file analysis showed that in all of the cases beam was not put on hold, so the second case is also unlikely. These results approve that the leaves speed is stable.
Number of deviations suddenly grows when leaves speed is 2.4 cm/s. The curves correlate weakly with each other, the average linear correlation coefficient $r = 0.17$ (standard deviation $\sigma = 0.28$). This means that the measured deviations occur not due to systematic but because of random errors.

When gantry position is at 270° leaves move overcoming gravity. We can see that this has an impact on the stability of leaf movement as leaves moving vertical have 62% more deviations than moving horizontally.
Interleaf transmission should be 0.5% smaller than nominal vendor value. Varian MLC interleaf transmission maximum value is 5%. Largest measured interleaf transmission value was 3.97%.
Conclusions

- Largest measured positioning deviation was 0.103 mm ± 0.035 mm, P = 0.95. It's 10.3% of permissible 1mm deviation. Multileaf collimator meets the requirements for positioning accuracy.
- There was no significant influence by gantry and collimator position and leaf travel speed for leaf positioning accuracy.
- Results acquired with EPID correlated with results acquired with Kodak film.
Conclusions (2)

- MLC also meets the requirements for leaf travel speed stability. It was confirmed by DynaLog file analysis.
- Used method was not suitable to evaluate absolute value of errors of measured travel speed instability since deviations were only hundredth of a percent from mean value.
- Number of deviations increases if leaf travel speed increases or gantry position is set to 270° or 90°.
- MLC Interleaf transmission also meets the requirements. Largest interleaf transmission value was 3.97%
Thank You!