

Independent checks of linear accelerators equipped with multileaf collimators

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Introduction

National Radiation Protection Institute (NRPI) provides independent checks of therapeutic equipment as a part of state supervision. In the end of 2003, the audit was broadened for linear accelerators equipped with multileaf collimators (MLC). NRPI provides TLD postal audits and on-site independent checks. This contribution describes tests for multileaf collimators and intensity modulated radiation therapy (IMRT) technique that are accomplished within the independent on-site check of linear accelerators.

The character and type of tests that are necessary to pursue for multileaf collimator depends on application technique. There are three basic application of the MLC. The first we call „static MLC“ and it serves for replacing conventional blocking or for adjusting the field shape to match the beam's-eye view projection of a planning target volume during an arc rotation of the x-ray beam. This procedure is called conformal radiotherapy. The most advanced technique with MLC is intensity modulated radiation therapy. The dose can be delivered to the patient with IMRT in various different ways: dynamic MLC, segmented MLC and IMRT arc therapy.

Dynamic MLC (sliding window technique) is used for a fixed gantry position, when the opening formed by each pair of opposing MLC leaves is swept across the target volume under computer control, with the radiation beam on, to produce the desired fluence profiles. This technique is used in the Czech Republic.

Segmented MLC (step-and-shoot technique) uses a series of multiple segment fields, in which each field consists of a series of MLC shapes delivered from the same gantry angle, so that an intensity-modulated field intensity is delivered. The multiple segment fields are set up at selected orientations of the gantry under computer control. The radiation is turned on only when the MLC leaves are stopped at each prescribed segment position. This technique isn't used in the Czech Republic yet, but is available.

Intensity-modulated arc therapy uses multiple irregular fields shaped with MLC during gantry rotation instead of rotating a slit field around the patient as done with tomotherapy. This technique isn't used in the Czech Republic yet.

Material and methods

The methodology of independent checks for MLC was adjusted to the modes in which MLC are being used. In the Czech Republic, frequently it is for conformal radiotherapy. However, there are three workplaces using IMRT with dynamic MLC. In the future, at least 7 other workplaces are going to treat patients with IMRT. Very important is concrete type of linear accelerator. In the Czech Republic, three different types of linear accelerators are in radiotherapeutic workplaces: Varian, Elekta, Siemens. Only Varian accelerators are used for IMRT with dynamic MLC. Elekta provides segmented MLC but isn't yet clinically used in CR. Elekta accelerators are used in the CR only for conformal radiotherapy. Siemens accelerator is found only in one workplace and is utilized for static conventional treatment.

For static MLC, following parameters are checked: Accuracy of leaf positioning, Reproducibility of leaf positioning, and Output factors for MLC shaped fields. These tests are not sufficient for dynamic MLC,

because these are much more sensitive to the operation of the MLC than conventional static treatments and there are other indispensable aspects one must consider. Except parameters mentioned above, within the independent check Average leaf transmission, Dosimetric leaf separation (Varian and Elekta only), Energy stability for IMRT fields, Sweeping gap for output at multiple gantry and collimator angles, Homogeneity, symmetry, and reproducibility for IMRT fields, and Stability during discontinuous irradiation will be verified. All parameters, their description, and tolerances are shown in table 1. Tolerances were taken from [5] and in future with growing experience can be changed.

Mode	Parameter	Tolerance	Description
Static, segmented, dynamic MLC	Accuracy and reproducibility of leaf positioning	± 1 mm	Deviation between actual and planned leaf position for various geometries (different for static and dynamic MLC mode) using film dosimetry.
	Output factors for MLC shaped fields	± 2 %	Deviation between measured value of output factor for MLC field and value computed by TPS for this field, test is taken for four different geometries (the same as for TLD MLC audit).
Segmented and dynamic MLC IMRT	Stability of average leaf transmission	± 5 %	Stability of the amount of radiation that passes over closed banks of leaves – deviation between measured value and value registered in TPS.
	Dosimetric leaf separation	± 5 mm	Stability of rounded leaves correction factor - deviation between measured value and value registered in TPS.
	Energy stability for IMRT fields	± 2 %	Stability of relative responses ratio under two depths (10 cm and 5 cm) for fractured IMRT field in comparison to the conventional field.
	Homogeneity and symmetry for IMRT fields	± 6 % ± 3 %	Homogeneity and symmetry for IMRT field using film dosimetry. IMRT field is produced by 1 cm wide and 10 cm long stripe that is continuously moving from one side to the other (sweeping gap). This results in irradiation of square regular field 10×10 cm ² .
	Sweeping gap for output at multiple gantry and collimator angles	± 3 %	Stability of relative responses for IMRT field (sweeping gap) under different gantry and collimator
	Reproducibility for IMRT fields	± 2 %	Deviation in responses for IMRT field (sweeping gap) delivered at different times.
	Stability during discontinuous irradiation	± 3 %	Deviation in responses for fractured IMRT field and conventional field.

Table 1. Parameters tested within independent check for MLC in static, segmented and dynamic mode and for IMRT

For tests called Accuracy of leaf positioning, Reproducibility of leaf positioning and Homogeneity, symmetry and reproducibility for IMRT therapeutic films Kodak X-omat V are used. Output factors for MLC shaped fields are measured with cylindrical ionization chambers in water phantom. Other parameters (for dynamic MLC) are performed in solid tissue equivalent phantom made by Wellhofer called I'mRT phantom (Fig. 1) into which it is possible to insert ionization chamber.

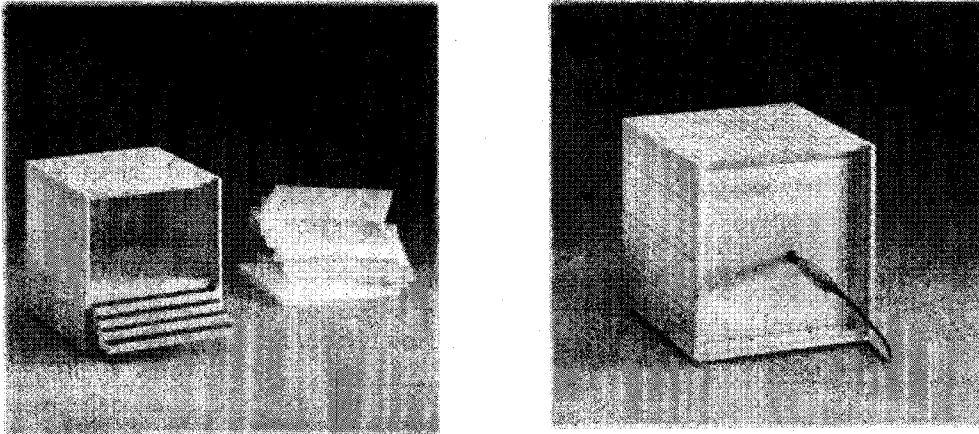


Figure 3. I'mRT phantom that is being used within independent check of dynamic MLC

Results and discussion

Independent checks for static MLC were performed for 8 accelerators (7 Varian, 1 Elekta). Results from dosimetric measurements of output factors for reference field and irregular field are shown in table 2. Comparison with results obtained from TLD postal audits can be made, because selected TLD results are attached. Geometries for measuring output factors within on-site audit were unified with geometries used in TLD postal audit (fig. 2).

Methodology for independent check for MLC and IMRT was written and two pilot measurements with dynamic MLC were performed. Files necessary for MLC patterns were created in the software Shaper. In principle, it is possible to perform audit for segmented MLC. For this mode NRPI doesn't have created MLC files and cooperation with given workplace would be essential.

Linear accelerator	Energy		Deviation measured and stated value for dose			
			Reference field		Irregular field	
	On-site	TLD	On-site	TLD	On-site	TLD
Clinac 2100 C	6 MV	6 MV	-0,3	-1	-0,8	-1,3
Clinac 2100 C/D	6 MV	18 MV		2,5		0,1
Clinac 2100 C/D	6 MV	6 MV	0,2	1	-0,3	-0,8
Clinac 2100 C/D	6 MV	18 MV	0,8	2,6	-1,7	2,2
Clinac 2100 C/D	6 MV	6 MV	0,9	0,1	-0,1	-0,1
Clinac 2100 C/D	6 MV	18 MV	-0,2	1,7	0,4	-0,7
Clinac 2100 C/D	18 MV	18 MV	0,1	-0,1	-0,4	-1,8
Elekta	6 MV	6 MV	-0,1	2	-0,9	1,2

Table 2. Results from dosimetric measurements of output factors for reference field and irregular field

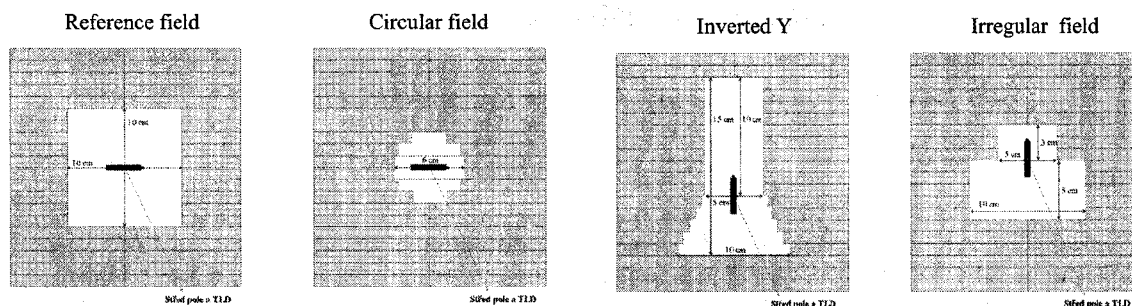


Figure 2. Geometries for on-site and TLD postal audits – measuring of output factors for MLC shaped fields: square $10 \times 10 \text{ cm}^2$, circle $\text{Ø } 6 \text{ cm}$, inverted with max. dimensions 15 cm and 10 cm , irregular field with max. dimensions 8 cm and 10 cm . The arrows show the placement of TLD capsule or ionization chamber

Conclusion

Independent audits represent an important instrument of quality assurance. Methodology for independent check of static MLC was successfully verified on two types of accelerators: Varian and Elekta.

Results from pilot measurements with dynamic MLC imply that the methodology is applicable for Varian accelerators. In the future, the experience with other types of linear accelerators will contribute to renovation, modification, and broaden independent checks methodology.

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