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Evaluation of a transmission quality assurance device mounted on a gantry of LINAC for 4 MV X-ray beam

H Yokoyama[1, 3], H Kojima[3], A Takemura[2], T Nguyen[1], S Ueda[3], K Noto[3], H Adachi[3]

1 Division of Health Sciences, Graduate School of Medical Sciences, Kanazawa University, Japan
2 Faculty of Health Sciences, Institute of Medical, Pharmaceutical and Health Sciences, Kanazawa University, Japan
3 Department of Radiological Technology, Kanazawa University Hospital, Japan

KANAZAWA UNIVERSITY

INTRODUCTION

The Integral Quality Monitor (IQM) (iRT Systems GmbH, Koblenz, Germany) is known as the X-ray transmission quality assurance (QA) device. It is mounted on the gantry of a linear accelerator and can be used for QA of a radiotherapy plan (Figure 1). It shows the measurements as "IQM signal count," which is not an absolute dose. Several studies have evaluated the sensitivity of the IQM in detecting multi-leaf collimator (MLC) position error for pre-treatment QA. One of them reported that a large-area ionization chamber had a great advantage in detecting systematic MLC error because of the chamber's large, sensitive volume, whereas the other devices could not detect the small range of MLC errors. However, most of the previous studies only investigated a 6 MV X-ray beam or higher energy beams, and evaluation of the IQM using a 4 MV X-ray beam hardly have been reported. Thus, the characteristics of the IQM for plans with a 4 MV X-ray beam that is often used in Japan must be evaluated.

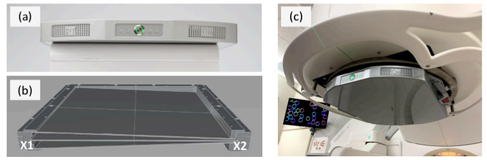

Figure 1 (a) The Integral Quality Monitor, (b) A wedge-shaped large volume gradient ionization chamber of the IQM, (c) The IQM mounted on the gantry of a linac

AIM

The purpose of this study was to evaluate the sensitivity of the IQM for systematic MLC position error with a 4 MV X-ray beam.

METHOD

The IQM was attached to the head of a linear accelerator, Elekta Infinity (Elekta, Stockholm, Sweden). Three conformal radiation therapy (breast, orbit, and spine), 1 IMRT (sinus) and 2 VMAT (prostate and pelvis) plans using a 4 MV X-ray beam were used to investigate the MLC error sensitivities. The errors for all leaves of both sides were added position error (Figure 2), ±1.5 mm as systematic open/close and ±3.0 mm as systematic shift for conformal plans, and ±1.0 mm as systematic open/close and ±3.0 mm as systematic shift for IMRT and VMAT plans. Dose measurement with a farmer type chamber (PTW GmbH) inserted into water phantoms (Figure 3) was also performed in the same way for comparison with the IQM results (Figure 4). The dose with/without the MLC errors for each plan was delivered and the cumulative signal counts or doses were measured with the IQM or farmer chamber, respectively. The difference of both was calculated based on the results of original delivery using the equations (1) and (2).

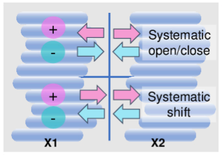

Figure 2 The MLC position error patterns

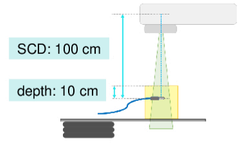

Figure 3 The geometry of the farmer chamber and solid water phantoms

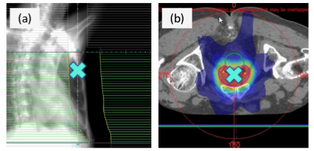

Figure 4 The examples of treatment field image consist of the MLC and dose distribution. The X marks show the measured points of (a) the breast and (b) the prostate.

$$S_{difference}[\%] = \frac{S_{error} - S_{original}}{S_{original}} \times 100 \quad \ldots(1)$$

$S_{difference}$: the difference of cumulative signal counts
$S_{original}$: cumulative signal count without the MLC error
S_{error}: cumulative signal count with the MLC error

$$D_{difference}[\%] = \frac{D_{error} - D_{original}}{D_{original}} \times 100 \quad \ldots(2)$$

$D_{difference}$: dose difference
$D_{original}$: measured dose without the MLC error
D_{error}: measured dose with the MLC error

RESULTS

- **Conformal plans**

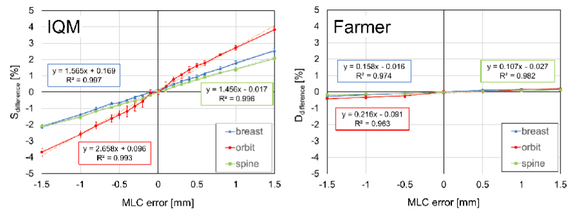

Figure 5 Evaluation of the sensitivity for systematic open/close MLC position error for each treatment site
The differences of cumulative signal count and dose between the original delivery and delivery with the MLC error in conformal plans.

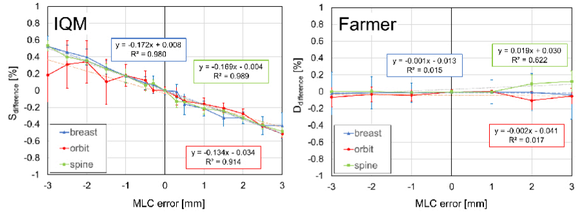

Figure 6 Evaluation of the sensitivity for systematic shift MLC position error for each treatment site
The differences of cumulative signal count and dose between the original delivery and delivery with the MLC error in conformal plans.

The cumulative signal count error of the IQM demonstrated a linear relationship with the magnitude of the MLC error as it increased and decreased although the farmer chamber could hardly detect the MLC position errors (Figure 5).
The conformal plan of orbit was affected the most by the systematic open/close MLC position error (Figure 4). It was considered that the MLC position error was relatively large because the treatment field size of orbit was smaller than the others.

The IQM had a much stronger correlation than the farmer chamber (Figure 6).
The result of orbit had a large standard deviation of the three measurements (Figure 6). Because the plan was a small treatment field and low prescription dose, it was given smaller counts than other plans. Thus, the IQM could not get enough counts to be stable at the end of dose delivery, and the plan of orbit had a larger variation. Even if the treatment field is small, it is considered that the IQM can show a stable result in cases of plans delivering adequate dose such as IMRT and VMAT plans.

- **IMRT and VMAT plans**

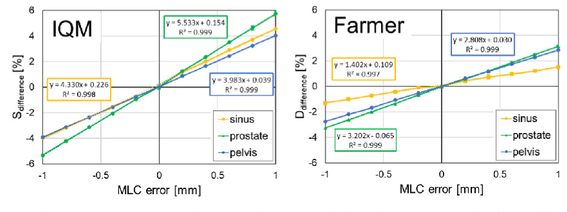

Figure 7 Evaluation of the sensitivity for systematic open/close MLC position error for each treatment site
The differences of cumulative signal count and dose between the original delivery and delivery with the MLC error in IMRT and VMAT plans.

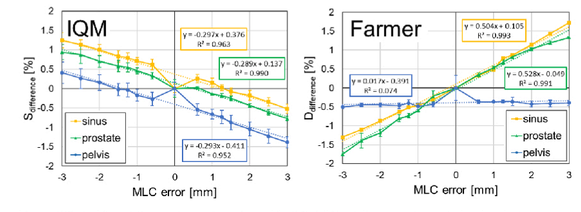

Figure 8 Evaluation of the sensitivity for systematic shift MLC position error for each treatment site
The differences of cumulative signal count and dose between the original delivery and delivery with the MLC error in IMRT and VMAT plans.

The IQM detected the same magnitude of the systematic open/close MLC position error as a larger difference than the farmer chamber, although the correlations were comparable (Figure 7).
Both detectors had the greatest impact on the prostate plan, and especially in the farmer chamber, the sinus plan was less affected. Of the three plans, only the sinus was IMRT and one of the five beams was irradiated. This was thought to be due to a lower prescription dose than the other two, as well as the conformal plans.

The IQM results showed almost the same gradient at all treatment sites, and the farmer results depended on the plans (Figure 8).
The cumulative signal counts of the IQM with MLC position error were sometimes almost the same as that without the MLC error. IMRT and VMAT were planned with steep dose gradients. Therefore, the treatment fields did not simply shift with the shift of MLC when these were compared with conformal plans. This could cause the IQM to show the same cumulative signal counts even if there were an MLC position error.
The farmer chamber could not detect the MLC position errors of the VMAT plan of the pelvis and did not have any correlation. However, the IQM was affected by them (Figure 8). This was planned with two arcs. It was considered that the MLC position errors of both arcs canceled each other out because the farmer chamber was placed on the couch and measured. In contrast, the IQM was mounted on the gantry, therefore that did not occur.

CONCLUSIONS

- The IQM was more sensitive to the MLC error than the dose measurement with the farmer chamber.
- The IQM was able to detect the systematic open/close MLC position errors in IMRT and VMAT plans with high sensitivity.
- The IQM could detect the systematic shift MLC position errors in IMRT and VMAT plans.
- We found that the IQM always could detect the MLC error even if only the position of the treatment field was shifted, and the field size and shape were correct. However, note that the IQM sometimes missed the error detection of the MLC position in the IMRT and VMAT plans.
- In summary, the IQM is more sensitive to the MLC error than the dose measurement with the farmer chamber for a 4 MV X-ray beam because of a large ionization volume.

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CONTACT INFORMATION

Haruna Yokoyama

13-1, Takara-machi, Kanazawa, Ishikawa, Japan 920-8641
Email: harunayokoyama@staff.kanazawa-u.ac.jp