CHAPTER 3

INTENSITY MODULATED RADIOTHERAPY QUALITY ASSURANCE USING MATRIXX

3.1 Introduction

Generally, the dose distributions obtained from a three dimensional treatment planning system have to be verified by dosimetric means in order to ensure that the prescribe dose of radiation is delivered to the right geometry and in right amount. QA plays an important role in radiotherapy. QA has become challenging and necessary as the machines are very sophisticated and treatment delivery has become very complex. IMRT is more demanding as far as QA is concern. Periodic verification of dosimetric data and radiation beam quality is required as part of QA programs in radiation oncology to ensure accurate delivery of treatment doses to patients. The QA process consists of verifying the absolute dose at a reference point, and also the relative or absolute planar isodose distribution.

In this chapter, we present the results of a dosimetric evaluation of a 2D ionization chamber array with the objective of its implementation for quality assurance and dosimetric verification of segmental intensity modulated radiotherapy (IMRT) in clinical environment. Further, we describe quality assurance (QA) results of 356 modulated beam using MatriXX (IBA Dosimetry, Sweden). IMRT using segmental multileaf collimator (sMLC) has been applied for different type of cancers at our institution. Dosimetric QA of all modulated beam is done as a part of pre treatment QA protocol.
3.2 Materials and Methods

MatriXX is a two-dimensional array of 1020 vented parallel plate pixel ion chambers. The pixel ionization chamber MatriXX consists of $32 \times 32$ chambers with a distance of 0.76 cm between chamber centres. Each chamber has a diameter of 0.45 cm and a sensitive volume of 0.08 cc. The center-to-center separation between the chambers is 0.762 cm, and the active field size is $24 \times 24$ cm$^2$. The minimum sampling acquisition time is 20 milliseconds the backscatter material in the device is a 2.2 cm thick water equivalent RW3 phantom. The inherent buildup material for photon beams is 0.33 cm.

The OmniPro-1'mRT (IBA Dosimetry, Sweden) software program is used for communication and data acquisition from MatriXX. The device has three markings on three sides exclusively designating the surface of the ion chambers. The markings are used for alignment purposes. The device was examined for measuring the absolute dose, relative output factor, dose rate, flatness, and symmetry of the photon beams. This arrangement set the surface of the chamber arrays at the isocenter. In addition, adequate amounts of plastic water were placed in front of the device to keep the surface of the chamber array at the center of modulations for all measurements. An absolute calibration of the MatriXX was done using the manufacturer recommended procedure prior to any measurements performed for this study. This procedure requires the user to obtain an absolute dose for fixed monitor units using a calibrated ion chamber. The measured absolute dose, temperature, and pressure are entered in the OmniPro-1'mRT software prior to an irradiation of the same MUs. The calibration factors are calculated by the software based on collected charges, after MatriXX has been irradiated for the same MU. This calibration factor is stored in the software.
MatriXX and is used for the subsequent measurements. MatriXX has an active field size of 24 x 24 cm$^2$, only 21 x 21 cm$^2$ active field size could be used without loss of penumbra. The reproducibility of the MatriXX calibration was verified by performing repeated measurements of the standard calibration beam. The significant benefit of an ionization chamber array is its simple handling by connecting it to a PC with a standard ethernet cable. Furthermore there is no dead time during the real-time measurement and after a calibration it is possible to measure the dose directly. The resolution is worse than the resolution of films or EPIDs but there is a good agreement between films and ionization chambers for verification of radiotherapy plans as reported by Spezi et al (2005) and Stasi et al (2005).

MatriXX is equipped with an onboard micro controller system, which manages the acquisition process. The read-out of collected data is carried out with a constant sampling rate of 10 ms.

The onboard firmware calculates the difference between subsequent readings and detects overrun conditions on the counters. A multiple overrun is excluded due to the TERA clock frequency of 5Mhz, which would allow a maximal increase of 50000 counts per read-out cycle.
Figure 3.1 Imrt MatriXX from Iba dosimetry, Sweden
3.2.1. Pre-irradiation

Like other ion chambers, MatriXX needs a certain dose of pre-irradiation before the chamber signal reaches a stable value 1. It is recommended to pre-irradiate MatriXX with an open field of 24x24cm in size. The dose recommended for this pre-irradiation is 5 Gy for 1% accuracy and 10 Gy for 0.5% accuracy (Müller; 2007).

Full saturation of the signal is reached after 20 Gy. The pre-irradiation has to be repeated every 3 hours if the single chambers have received less than 10 Gy during this period. After the device has been switched off, also for a short period, the pre-irradiation has to be repeated. Herzen et al (2007) concluded that a dose of approximately 10 Gy is required to reach a stable signal. MatriXX needs a warm up time of 45 minutes.

The process of equilibration is stochastic in nature, which means that the amount of pre-irradiation needed to reach the final conversion factor can be considerably longer on some of the pixels.

![MatriXX sensor pre-irradiation](image)

Figure-3.2 Reference signal for MatriXX sensor pre irradiation
3.2.2. Linearity

Figure 3.4 shows the linearity of the read-out signal for various beam qualities. A 6MV photon beam from Siemens primus accelerator was used for these measurements. MatriXX was placed at 100cm SSD with an additional build-up of 2 cm RW3. For doses ranging from 10 to 600 MU and integration times from 25 sec to 150 sec, no non-linearity could be detected within the measurement uncertainty (Müller, 2007).
3.2.3 Absolute Calibration of MatriXX

The user has the possibility to assign an absolute dose value to the readings of MatriXX. For this purpose, MatriXX has to be placed centered under the radiation source under the desired reference conditions (build-up, backscatter, SSD). MatriXX is then exposed to a known dose. The calibration is executed relative to the 4 innermost pixels. The software guides the user through the calibration process; it is possible to store the calibration factors for various beam qualities and to retrieve them for measurements with the relative radiation source. MatriXX uses the principle of vented air ion chambers. Sensors for both temperature and pressure are build-in in the device and can be used for an automatic correction of the air density. The readings of both sensors can be visualized in the software: Pressure: the read-out value (in mbar) can be compared to a high-precision, calibrated barometer. The barometer read-out
could be entered if it differs from the value internally revealed, a correction is then performed sensor nonlinearity.

### 3.2.4 Optimization of calculation grid of IMRT TPSs

The import of planned data in OmniPro-IMRT is done preferentially via DICOM RT. the planning system in use does not support DICOM export functionality, data can be exported also via RTOG, in some cases proprietary formats for specific TPSs are also available. The OmniPro-IMRT Software is designed for operation with various data sources (MatriXX, I'mRT-QA, radiographic and radiochromic film, EPIDs, TPSs), which have inherently very different pixel sizes and numbers. It is often desirable to make comparisons between different data sets using the same grids, which might be accomplished by integration of a fine grid to a coarser one or by linear interpolation of a coarse grid down to a finer one. In lower resolution grids, it is not sufficient to specify only the width of the grid, but also the position of the center of the grid. OmniPro-IMRT allows the specification of 2 modes.

One centerline the center of a pixel is in the center of the array 2 centerlines the touching corners of 4 pixels are in the center of the array for the reconstruction of finer grids, a 2-dimensional linear interpolation is used between the points of the coarser grid. It is not recommended to use the setting ‘cubic spline’ for the interpolation.

### 3.2.5 Comparison between TPS plan data and MatriXX measurement

MatriXX measures dose with cylindrical detectors in a 0.762 x 0.762 cm grid. As an approximation, the dose measured in 1 pixel could be seen as the integral over a
square with side length of 0.762 cm. For a comparison with the treatment planning data, TPS dose data have to be evaluated within the same grid. Moreover, it needs to be checked what kind of dose information is given by the TPS. XiO (version 4.34.02) treatment planning system is used to generate optimized IMRT plans. Oncor Expression linear accelerator, equipped with Optifocus MLC, is used to deliver the IMRT treatment.

3.3 Results and discussion

Mainly, a comparison of two-dimensionally calculated and measured data in several coplanar planes is performed. The flat-panel EPIDs show a good resolution and offer a possibility for real-time measurements but their calibration is complicated, as the signal being converted into dose. Radiographic (Childress et al 2005, Yeo et al 2004) as well as radiochromic (Todorovic et al 2006) films have a very good resolution but their handling is still very time consuming. Due to the calibration and scanning process, they cannot be applied for fast real-time measurements. The flat-panel EPIDs show a good resolution and offer a possibility for real-time measurements but their calibration is complicated, as the signal has to be converted into dose. A polystyrene backscatter plate is mounted under the sensor.

We have analyzed all beams using gamma, distance to agreement (DTA), profile comparisons, measured dose (relative/absolute), visual comparison and coefficient of correlation. We have noticed that gamma index and DTA are pass in more than 97% beam with a 3% and 3 mm passing criteria along with coefficient of correlation of 0.987 (SD 0.047).