An evaluation of two-dimensional array ion chambers for patient-specific quality assurance of Tomotherapy HDA™

การประเมินการทำงานหัววัดรังสีสองมิติชนิดไอออน สำหรับสอบทวนการวางแผนการรักษาผู้ป่วยด้วยเครื่องฉายรังสีโทโมเทอราปี รุ่น HDA™

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Submitted : Jan 31, 2023

Revised : Mar 8, 2023

Accepted : Mar 20, 2023

Abstract

Background: The MatriXX is a 2D array base on ion chamber detector that provides real-time dose measurement and ease of use. However, there are few studies on MatriXX for patient-specific quality assurance (PSQA) of Tomotherapy.

Objective: The purpose of this study is to validate the MatriXX for using as a PSQA tool for Tomotherapy HDATM at Ramathibodi hospital.

Materials and Methods: The MatriXX dosimetric characteristics were evaluated in terms of dose linearity, distance dependence, and directional dependence including field width (FW), pitch, and modulation factor (MF) were examined by varying the parameter based on the clinical use. For the clinical application, the gamma analysis results of ten prostate plans by MatriXX were evaluated. The location of detector effect was evaluated by shifting the virtual planning target volume (PTV) and ten breast plans were investigated.

Results: The dose response was linear for delivery time of 5-300 seconds. Source-to-detector distance (SDD) effect showed a good agreement with A1SL with a difference less than 1%. The directional response was showed a large discrepancy (0.5) at the rear part of the detector, which was the effect of MatriXX structure. The gamma passing rate (GP) for all plans that optimized by varying planning parameter were greater than 97% for 3%/3mm criteria. For clinical test, the average GP of ten prostate plans was 98.29±0.82% which pass the criteria of AAPM TG-148. In addition, the GP for virtual PTV for a location effect test were greater than 96% for all six directions. The results indicated that location did not affect to the MatriXX measurement. However, for clinical breast cases, which were large field size and almost located in non-isocenter, the results showed a low GP (< 50%) for non-shifting the detector. It showed an increasing of average GP up to greater than 88% when shifting almost dose distributions to cover the whole effective detector area.

Conclusion: This study indicated that MatriXX was an effective and reliable dosimeter tool, and it could be used for PSQA. However, the use of MatriXX for PSQA in clinical cases with a large radiation field and non-isocenter should be concerned.

Keywords: Helical Tomotherapy, Patient-Specific Quality Assurance, Two-dimensional array ion chambers

บทคัดย่อ

หลักการและเหตุผล: เมทริกซ์ คือหัววัดรังสีสองมิติแบบอาเรย์ ชนิดไอออน สามารถอ่านค่าได้ทันทีและใช้งานง่าย อย่างไรก็ตาม การศึกษาของหัววัดสำหรับสอบทวนการวางแผนการรักษาผู้ป่วย ด้วยเครื่องโทโมเทอราปีมีน้อย

วัตถุประสงค์: เพื่อตรวจสอบหัววัดรังสี เมทริกซ์ สำหรับสอบทวนการวางแผนการรักษาผู้ป่วยด้วยเครื่องโทโมเทอราปี รุ่น HDATM ในโรงพยาบาลรามาธิบดี

วัสดุและวิธีการ: คุณสมบัติเชิงรังสีนั้นประเมินในส่วน การทดสอบความสัมพันธ์เชิงเส้นของการนับวัดรังสี การตอบสนองต่อระยะทางที่ได้รับรังสี และการตอบสนองต่อทิศทางการเข้าของรังสี รวมด้วย field width (FW), pitch, และ modulation factor (MF) ตรวจสอบโดยเปลี่ยนแปลงพารามิเตอร์ตามค่าที่ใช้ทางคลินิก การทดสอบทางคลินิกจะประเมินผลค่าแกมมาสำหรับแผนการรักษามะเร็งต่อมลูกหมาก 10 รายที่ได้จากหัววัด ผลกระทบจากตำแหน่งนั้นประเมินจากแบบจำลอง planning target volume (PTV) และแผนการรักษาของมะเร็งเต้านม 10 ราย

ผลการศึกษา: ความสัมพันธ์ของปริมาณรังสีที่นับวัดกับเวลาที่ใช้ 5 ถึง 300 วินาทีเป็นเส้นตรง ผลกระทบจาก SDD ไปทางเดียวกับหัววัดรังสี A1SL โดยแตกต่างน้อยกว่า ±1% การตอบสนองต่อทิศทางของรังสีแสดงความแตกต่างมากสุด (0.5) ที่ด้านหลังจากส่วนประกอบของหัววัด การเปลี่ยนแปลงพารามิเตอร์ได้อัตราค่าผ่านแกมมามากกว่า 97% ที่ดัชนีแกมมา 3%/3 มิลลิเมตร อัตราค่าผ่านแกมมาเฉลี่ยมะเร็งต่อมลูกหมาก 10 ราย เท่ากับ 98.29±0.82% ซึ่งผ่านเกณฑ์ AAPM ฉบับที่ 148 ค่าเฉลี่ยอัตราค่าผ่านแกมมาของ PTV ทั้ง 6 ทิศทางมากกว่า 96% บ่งชี้ว่าตำแหน่งไม่ส่งผลต่อการนับวัด กรณีมะเร็งเต้านมแสดงอัตราค่าผ่านแกมมาต่ำ (< 50%) สำหรับแผนที่ไม่เลื่อนหัววัด ขณะที่ค่าเฉลี่ยอัตราค่าผ่านแกมมาเพิ่มขึ้น 88% สำหรับแผน ที่เลื่อนหัววัดครอบคลุมตำแหน่งที่มีการกระจายปริมาณรังสี

ข้อสรุป: การศึกษานี้บ่งชี้ว่า หัววัดรังสี เมทริกซ์ เป็นเครื่องมือที่มีประสิทธิภาพสามารถใช้สำหรับสอบทวนการวางแผนการรักษาผู้ป่วย อย่างไรก็ตาม สำหรับการใช้งานหัววัดนี้กรณีที่มีขนาดลำรังสีใหญ่และไม่อยู่กึ่งกลางนั้นควรระวัง

คำสำคัญ: โทโมเทอราปีชนิดเกลียวหมุน, การสอบทวนการวางแผนการรักษาผู้ป่วย, หัววัดรังสีสองมิติชนิดไอออน

J Thai Assoc Radiat Oncol 2023; 29(1): R89-R107

Introduction

Recently, advanced techniques such as intensity-modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) have been widely used for radiation treatment. Helical Tomotherapy is one of the machines that has been developed to achieve the advanced technique and become commonly used.

Tomotherapy's goal is to deliver a highly conformal dose distribution with steep dose gradients to the target volume while sparing normal tissues. The operation of the machine is quite complicated, the modulated dose distribution was generated from the high-speed binary multileaf collimator (MLC) combined with ring gantry-based technology. The dose delivery using gantry rotation synchronize with a couch translation into the bore[1]. Therefore, each patient planned dose need to be verified to ensure accurate delivery. This procedure is Patient-specific Quality Assurance (PSQA).

Patient-specific QA or delivery quality assurance (DQA) for Helical Tomotherapy is performed to identify discrepancies between treatment planning dose calculation and delivered dose prior patient treatment. The purpose is to detect the gross error in radiation delivery and minimize all potential sources of error. To ensure delivery accurately and patient safety, an adequate system of DQA must be implemented. Based on the American Association of Physicists in Medicine (AAPM) TG-148, Gafchromic EBT3 films and A1SL ionization chambers are a goal standard dosimeter for planar dose and point dose distribution evaluation in PSQA of Helical Tomotherapy[2-5]. Radiochromic film is a highly efficient QA tool for planar dosimetry due to its dosimetric characteristics such as high spatial resolution, near-tissue equivalent, and less energy dependence[6-8]. However, there are several factors that limit the radiochromic films dosimetry, time-consuming from a saturation of the optical density response, uncertainties of films procedure, and cannot be reusable[6, 8, 9]. Currently, there are several commercials two-dimensional (2D) as well as three-dimensional (3D) detectors array have been introduced to use for PSQA[4, 10]. These dosimeters provide instantaneous dose distribution readout and analysis including easily operated.

The MatriXX is one of the detectors that is widely used in IMRT and VMAT, which were delivered by C-arm based[11-14]. It is a 2D detectors array that consists of a bundle of ionization chambers, which is not required for frequent sensitivity calibration, easy setup, and provide real-time dose measurement[11, 15]. However, there are a few numbers of studies on MatriXX for dosimetric characteristic including pre-treatment verification for Tomotherapy. There are some studies evaluated the Matrixx to be used as a QA tool for IMRT and VMAT plan for Tomotherapy. The results showed that the gamma passing rate (GP) was greater than 90%, which was consistent with TG-148 recommendation[14, 16]. However, the previous studies did not include the limitation of effective field size of MatriXX, which was affected on the large irradiation field, validation is required. In addition, there are a few numbers of studies on MatriXX for dosimetric characteristic including pre-treatment verification for Tomotherapy. Therefore, the purpose of this study is to validate the dosimetric characteristics of MatriXX and evaluated the detector for using in a clinical application as a PSQA tool for Tomotherapy HDATM at Ramathibodi hospital. The present study, a comprehensive MatriXX response was

carried out in terms of the dosimetric characteristic test, planning parameters effect test, and clinical test. For clinical application, we selected the two majority cancer sites that are treated in our center, which were prostate and breast cancers. In addition, a location evaluation was performed for breast cancer plans due to these cases had a large field and located in a non-center of the body.

Materials and Methods

This study using the MatriXX Evolution, a 2D array detector that based on ionization chambers, manufactured by IBA Dosimetry GmbH, Schwarzenbruck, Germany. The array consists of 1020 vented ion chambers, arranging in a 32×32 cm2 grid cover an active measurement area of 24.4×24.4 cm2. Each chamber volume is 0.08 cm3 and the distance between the chamber center is 0.762 cm. This array detector combination with IBA miniPhantom (IBA Dosimetry GmbH, Schwarzenbruck, Germany), which is a water equivalent solid phantom that use for PSQA verification **(Figure 1)**. All experiments were performed on Tomotherapy HDATM system (Accuray, Sunnyvale, CA), which provide a nominal 6 MV-FFF beams and dose rate of 870 monitor unit (MU)/min. The machine has 85 cm

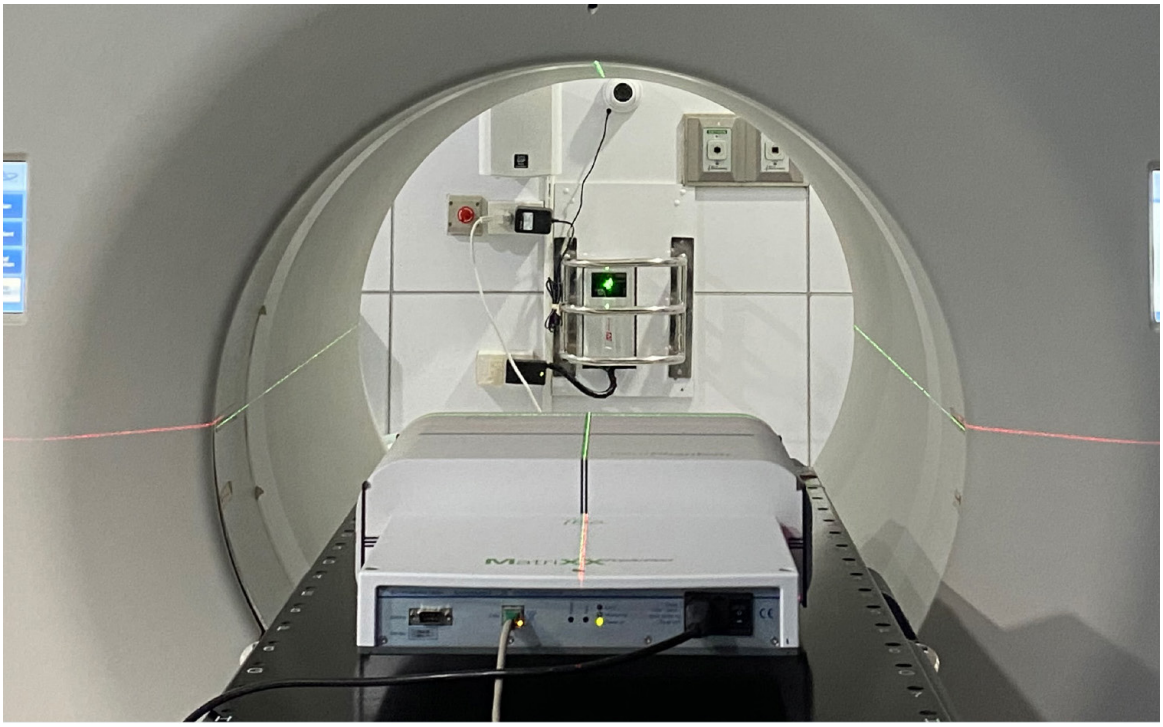


Figure 1 The MatriXX with miniPhantom for measuring on Tomotherapy HDATM at Ramathibodi hospital.

source to axis distance (SAD) and bore diameter. Tomotherapy has 64 leaves binary multileaf collimator (MLC) cover 40 cm in the transverse direction, with each leaf width of 0.625 cm at isocenter.

Prior to all experiments, the MatriXX have been calibrated for dose measurement following manufacturer instruction. A1SL ion-chamber (Standard Imaging, Middleton, WI), which is a standard detector for performed absolute dose following AAPM TG-51[17] of Tomotherapy machine was set combination with solid water phantom as the same condition as MatriXX within miniPhantom **(Figure 2)**.

All results were compared with the dose response that obtained from the four central chambers of MatriXX. In addition, the validation of the experiments using MatriXX and miniPhantom were analyzed using OmniproTM I'mRT software version 1.7.

Dosimetric characteristics test

The MatriXX dosimetric characteristics were evaluated in terms of dose linearity, distance dependence, and directional dependence. For this study, A1SL also used as a reference dosimeter for dosimetric characteristic test in terms of distance dependence.

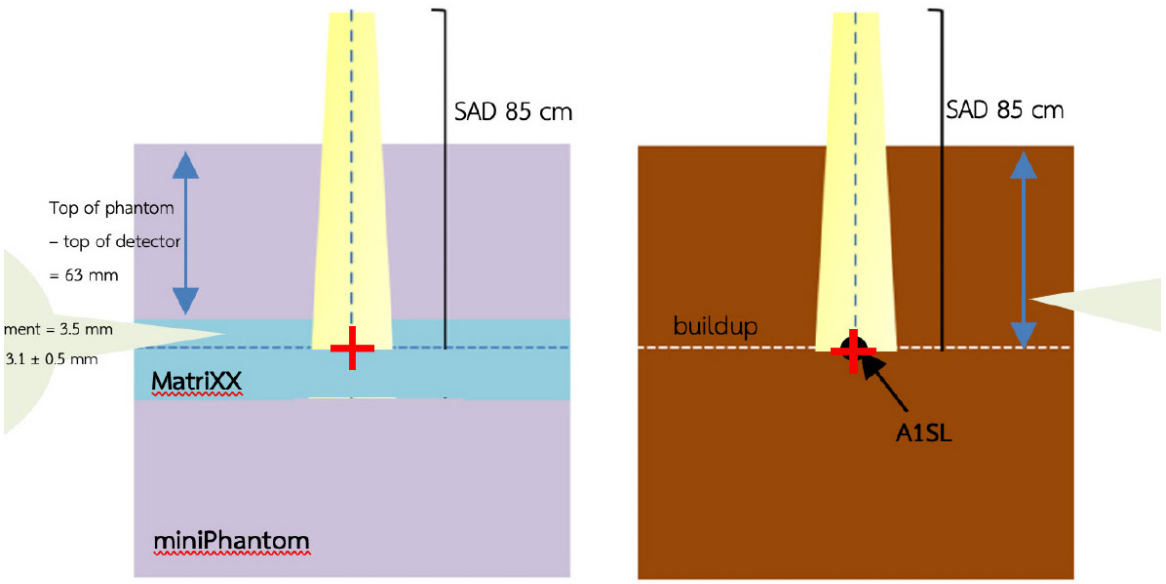


Figure 2 Schematic of calibration set-up for a) MatriXX and b) A1SL ion-chamber.

Linearity test was performed by varying beam on time from 5-300 seconds based on clinical use at Ramathibodi Hospital. The Tomotherapy machine-specific reference field size of 10×5 cm2 was used for delivery[3, 18]. This field size was also used for distance dependence and directional dependence test. All experiments were performed by using irradiation time of 10 seconds per each measurement following AAPM TG-148. The purpose of the linearity test was to evaluate the properties of detector reading that were proportional to the actual dose with a linear equation.

Distance dependence test were performed to estimate the effect of the varying distance of measurement on the detector response. The measurement was carried out by varying source to detector distance (SDD) by 85±5 cm, in 1 cm increment. The measured dose of MatriXX (normalized at 85 SSD) in each SDD was compared with A1SL.

For the directional dependence test, the purposed of this test was to evaluate the incident beam angle affects the MatriXX response. The gantry was varied from 0 to 360 degrees within a 7° interval, following the specific characteristics of the Tomotherapy machine that were split into 51 projections while delivering helical beams. The dose measurement was normalized to the dose response at the incidence angle of 0°.

Geometry planning parameters test

A cylinder virtual planning target volume (PTV) with a 5 cm diameter and 5 cm long was created as a target for test the geometry planning parameter effect on the DQA analysis, which was measured by MatriXX combination with miniPhantom. The field width (FW) and pitch parameters were varied while fix the modulation factor (MF) value of 2 that is a default value of TPS. This test was performed for FW with a static jaw of 1 cm and dynamic jaws of 2.5 and 5 cm. The variable of pitch in this test was used the magic numbers that purposed by Kissick et al.[19] ,which were 0.215, 0.287, and 0.430. In addition, the MF were varied 1, 2, 2.5, 3, and 5 while keep the setting defaults value of dynamic FW = 2.5 and pitch = 0.430. A total of fourteen plans were optimized by varying the planning parameters as the previous described in helical mode. In addition, the target PTV dose were prescribed to 2 Gy per fraction and the main criteria was 100% dose cover 95% volume of PTV based on a clinical routine of Ramathibodi hospital. The tolerance of the GP acceptance results should be more than 90% using the gamma criteria of 3%/3 mm according to AAPM TG-148 recommendation. The criteria of 2%/2 mm were additional analyzed to evaluate the small error effect. Two-way ANOVA and Kruskal-Wallis H test were used to analyze the statistic.

Clinical test

A. Patient-specific QA of MatriXX for prostate cancer

Ten prostate cancer plans that treated between 2017-2018 by Tomotherapy HDATM at Ramathibodi hospital were randomly selected. The position of MatriXX with MiniPhantom was set up using red laser and MV-CBCT imaging to minimize the set-up error. The agreement criteria were set following the AAPM TG-148 which is GP more than 90% with 3% /3 mm criteria, and 10% threshold with global analysis by Omnipr - I'mRT software[3]. The GP results for ten prostate plans of MatriXX measurement were compared with retrospective data of EBT3 films, which were previously measuremed at Ramathibodi hospital.

B. Patient-specific QA of MatriXX for breast cancer

For breast cases, the experiment was divided into two parts including location of detector effect and clinical breast cases. Because the main issues of breast case were large radiation field size and non-isocenter, most of the high dose distribution were not in the MatriXX detector area. Thus, the detector had to be shifted from the position obtained from the DQA plan by treatment planning.

B.1 Location effect of virtual PTV

The simple virtual PTV of a 10 cm diameter was created and used for location effect test. The DQA plans were evaluated by shifting the phantom for measurement in six directions, which were left-right lateral position, superior position including upper-lower couch shift position. All directions were shifted 5 cm from the isocenter of the detector as shown in **Figure 3**. The GP derived from DQA plans across six locations were analyzed and further determine the moving position of the sample group.

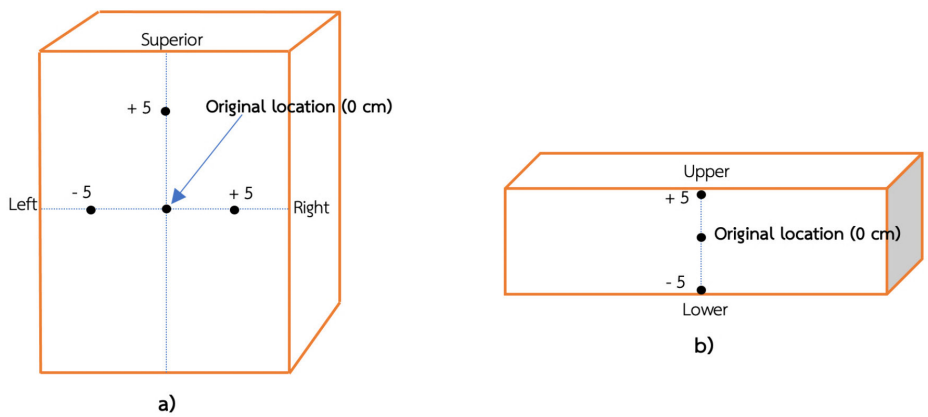


Figure 3 The location of virtual PTV of a 10 cm diameter for the measured dose plan on MatriXX a) front view showed the superior and lateral location and b) lateral view showed the upper and lower location.

B.2 Clinical breast cancer

Ten clinical breast cancer plans in 2021 that treated by Tomotherapy HDATM at Ramathibodi Hospital were selected, the treatment plans included both right and left side lesions. Typical of DQA process, the patient treatment plan was generated without moving phantom by fixing the isocenter of detector at the isocenter of the bore. We stated this location as an original position plan as shown in **Figure 4a**. Whereas corrected position plans were the DQA plans that shifting the detector to a position with mostly dose distribution covering especially in the high dose region, as shown in **Figure 4b**. The gamma analysis results were compared between the original position plans and corrected position plans. The 3%/3 mm gamma criteria and passing rate more than 90% were used to analyze based on AAPM TG-148 with gamma analysis results were used by global normalization method[3].

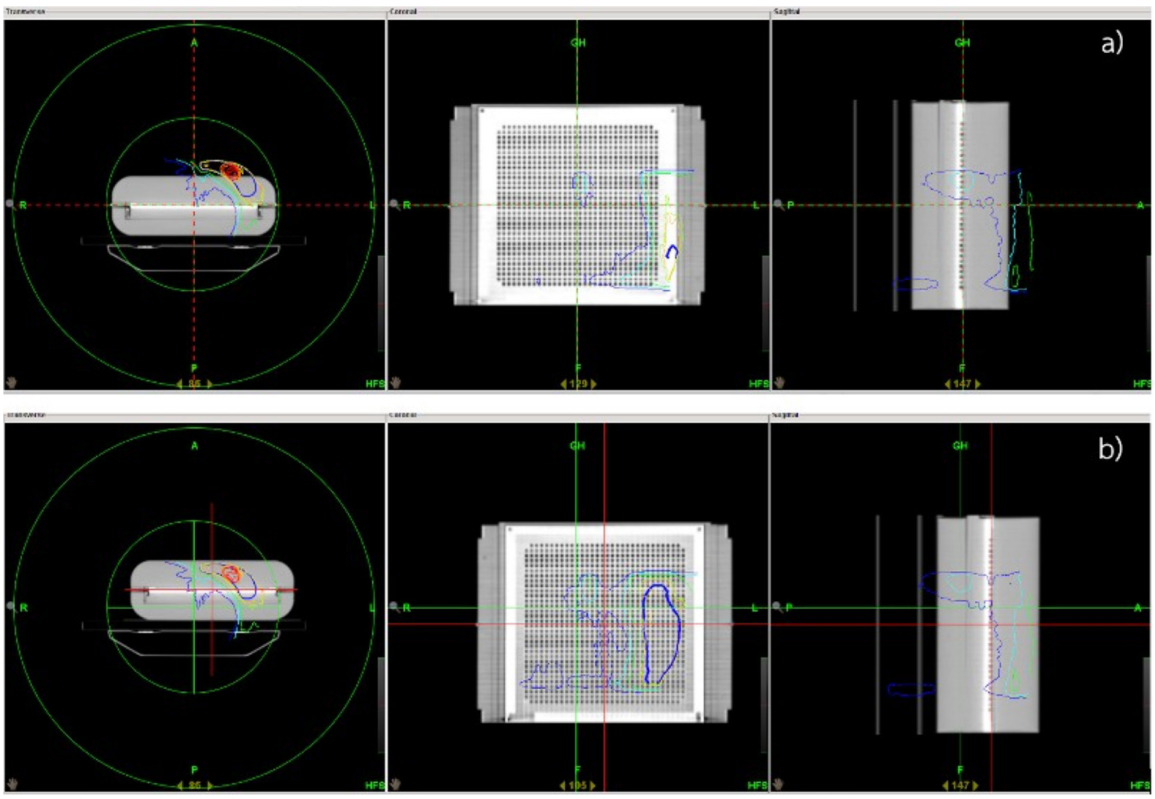


Figure 4 The DQA of breast plans a) original position and b) corrected position in MatriXX with miniPhantom.

Results

Dosimetric characteristics test

The dosimetric characteristics of MatriXX with miniPhantom showed good dose linearity. The relationship between the MatriXX dose response obtained from the averaging of the central four chambers and time delivery (5-300 s) were represented a linear line with a coefficient R2 equal to 1 as shown in **(Figure 5)**. For distance effect, the MatriXX response decreased when SDD increased. The results were corresponding to the A1SL measurement. The difference of relative measurement for varying the distance were within ± 1% with a maximum difference of 0.79% at SDD of 80 cm **(Figure 6)**. For directional dependence, the result depended on incident angle as shown in **(Figure 7)**. Especially in the rear part of the detector, the high variation showed at the gantry ranging from 70 ° to 112 ° and 245 ° to 287 ° incident angles, the directional response was 0.54 ± 0.03% and 0.55 ± 0.03%, respectively. Moreover, the result showed a maximum difference of dose response of 0.5 at a gantry angle of 266 °.



Figure 5 The MatriXX dose response at time delivery of 5-300 secs.

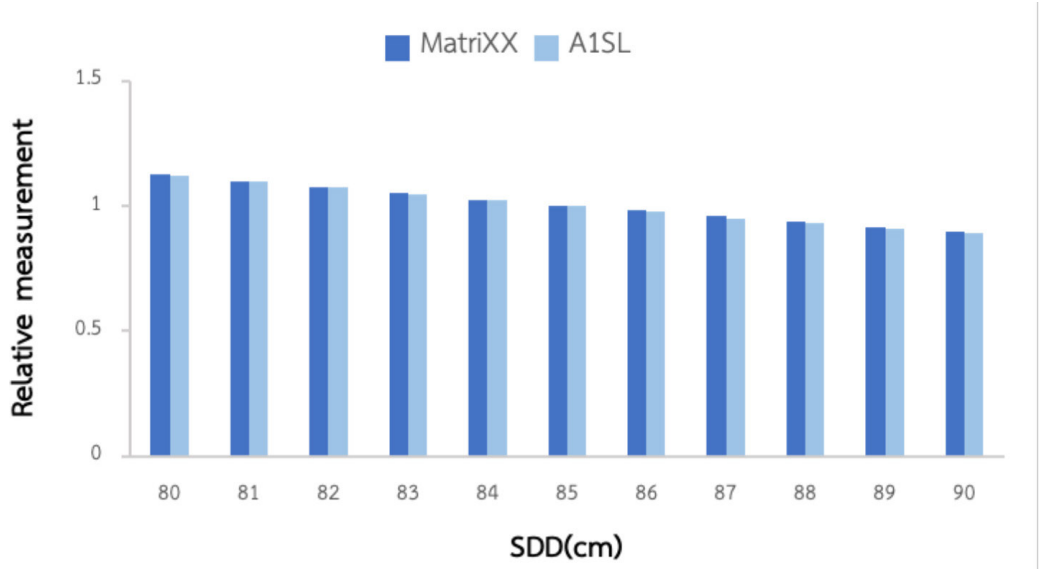


Figure 6 The SDD response on dose measurement for MatriXX and A1SL, normalized to 85 SDD cm.

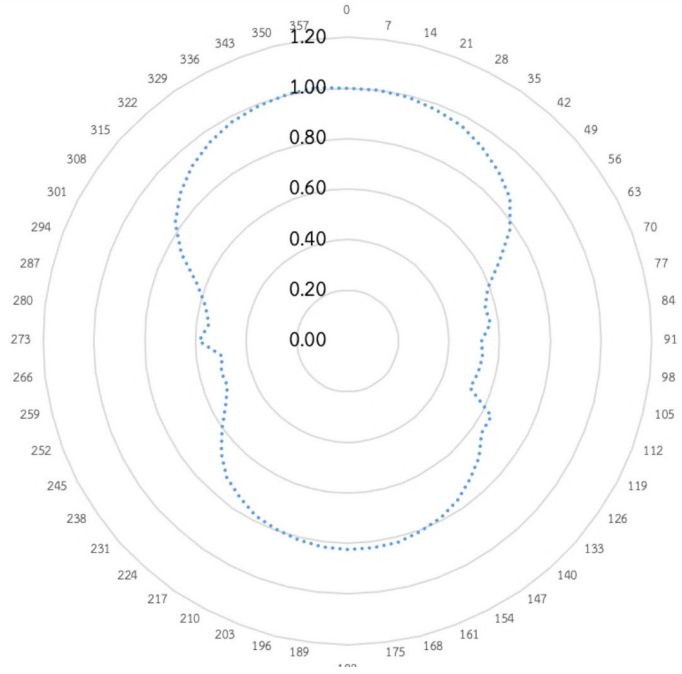


Figure 7 Dose response of average four central chambers with the variation of beam direction in full arc of 360 ° (the particular angle dose response was normalized to the incident angle of 0 °).

Geometry planning parameters test

All fourteen plans were optimized by varying the three different planning parameters: pitch, FW, and MF. The average of GP for all plans were greater than 97% and 90% with a gamma criteria of 3%/3 mm and 2%/2 mm, respectively. The mean and SD values for the gamma criteria of 3%,3 mm were 98.47 ± 0.45%, 98.57 ± 0.50%, and 98.57 ± 0.36%, while for the gamma criteria of 2%,2 mm were 98. ± 1.15%, 98.57 ± 1.37%, and 98.57 ± 1.45%, for various FWs and pitch of 0.215, 0.287, and 0.430, respectively. The average of GP for all plans for varying MF values were 98.32 ± 0.33%, 94.36 ± 0.97% of 3%/3 mm and 2%/2 mm, respectively. Although, the GP for stringent criteria of 2%/2 mm were lower than the gamma criteria of 3%3 mm, there were no significant difference with Two-way ANOVA and Kruskal-Wallis H test, by specifying p-value ($P > 0.05$) for all three planning parameters.

B. Patient-specific QA of MatriXX for breast cancer

B.1 Location effect of virtual PTV

For location effect, the high GP demonstrated 98.15±0.26% at the center position and slightly reduced when the position of detector was shifted to the lateral (96.78±0.20% and 96.58±0.20% for left and right side, respectively). However, the GP of all plans in six directions for simple PTV with a 10 cm diameter were greater than 96% with 3%/3mm criteria.

B.2 Clinical breast cancer

For clinical breast DQA plans, this study analyzed original and corrected position plans. Most original positions had GP lower than the corrected position that the high dose distribution covering the effective detector area. The result showed an increasing of average GP to greater than 88% for 3%/3 mm criteria. The GP results were low in some cases and also depended on the shape of dose distribution of the plan, limitation of detector such as an effective area and electronic part. However, the maximum increasing of GP was found up to 79.90% from the original position plan. Our results showed the GP were significantly increased when the phantom was shifted to the position that cover dose distribution for most of the plans as shown example plan in **(Figure 8)**. However, each patient breast instances were highly complex with individual anatomies and nodules, some plans did not agree with the corresponding results.

Discussion

Our study showed good dosimetric characteristics of MatriXX response for linearity and SDD effect. This result confirmed that the detector was suitable for measurement in Tomotherapy machine. Moreover, distance effect for MatriXX responses was similar to the reference dosimetry (A1SL) in the same condition with the variation within ±1%. For the 85 cm Tomotherapy bore, the range for this tested (±5 cm) are appropriated and safe to travel in the up and down phantom directions in this machine. For angle effect, our study showed that the response of

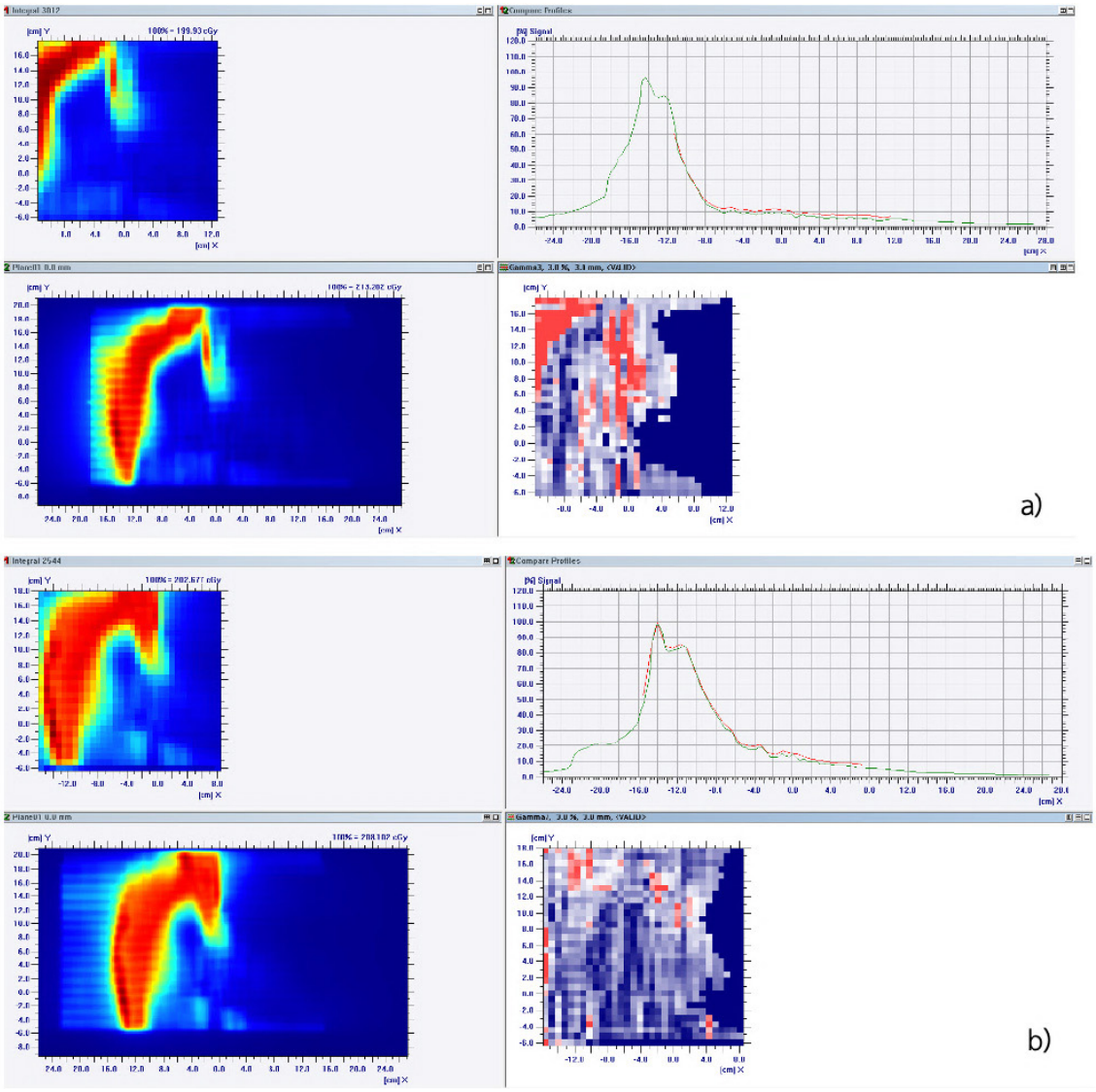


Figure 8 An example of gamma analysis for breast plans in a) original and b) corrected position by Omni-pro-I'mRT software.

MatriXX detector depended on incident beam angle. Especially in the rear part of the detector, it caused by the attenuation of the air-high Z interface in the MatriXX structure[13, 20]. However, for helical technique, which the beam was delivered with a small portion direct to the phantom per one rotation then directional effect of MatriXX was dilute[20, 21].

This consumption was clearly seen in the geometry plan parameter test that using helical irradiation.

The GP for all plans that optimized by varying FW, Pitch, and MF were greater than 97% and 90% for 3%/3mm and 2%/2mm criteria, respectively. According to the AAPM TG-148 requirements, the Tomotherapy system must have a GP of at least 90% at 3%/3 mm[3]. Although, the average GP was reduced when using a stringent of 2%/2 mm criteria, the value was more than 90% that regrading to TG-148 recommendation. The MatriXX response in this study assessed the impacted factors of TPS for Tomotherapy, where the values of these factors were based on clinical routine in our center. All results were supported by previous studies from Sresty et al.[16] and statistical analysis results were not statistically different (P-value > 0.05) for all three plan parameters. This indicated that the routine clinical use of geometry plan parameter for simple PTV was not affected on the MatriXX measurement results. However, the experiment results were based only on a virtual simple PTV and had no organ at risk while optimizing. The variable should be more observing in the clinical cases for various PTV sizes and locations.

For clinical test, the average GP of all DQA plans for the ten prostate cases demostrated a good agreement with requirements from AAPM TG-148 for patient-specific QA in Tomotherapy. The study found that the mean GP up to 98%, was in line with pervious study of MatriXX by Xu et al. and Sresty et al.[14, 16]. In addition, the result indicated a moderate correlation of 0.53 between the MatriXX measurement and EBT3 films. Nevertheless, the comparatively results were investigated in a small sample size (ten sample plans) due to the limited of EBT3 film information which was a retrospective data. With a small sample size, the r value obtained by correlation statistical analysis had lower creditability than the large size of sample group[22]. Therefore, this sample size should be considered as a limitation of the interpretation of the correlation analysis in this research. However, the GP of ten prostate plans by MatriXX with miniPhantom pass the criteria showed that this detector could be used for pre-treatment verification on Tomotherapy machine.

We observed that the gamma pass rate was not dependent on the MatriXX location, which was clearly showed in the location effect test of simple PTV that provided the GP above 96% (3%/3mm) for all shifting direction. Our results indicated that shifting did not affect to GP measured by MatriXX for virtual PTV of 10 cm diameter. The results were consistent with results of the uniformity test from MatriXX calibration.

However, the GP was mainly depended on the dose distribution that covered the effective area. This state in clinical breast case results, which the GP significant increased when shift the high dose distribution to almost cover the detector. In addition, the results also depend on the shape of dose distribution of the plan, limitation of detector such as an effective area and electronic part including machine configuration[14, 23].

In breast case that had a large body, the original position was located far out of the axis as shown example in **(Figure 9)**. One of the sample cases for limitation of machine and an effective area of the detector founded. Therefore, the phantom had to be moved a lot in an upper direction. However, moving the aforementioned more than 6 cm causes the operation safety to prohibit couch movement due to the safety of Tomotherapy bore **(Figure 10)**. The limited detector area that could not cover the entire high-dose region results in low GP values. For this reason, the use of MatriXX for

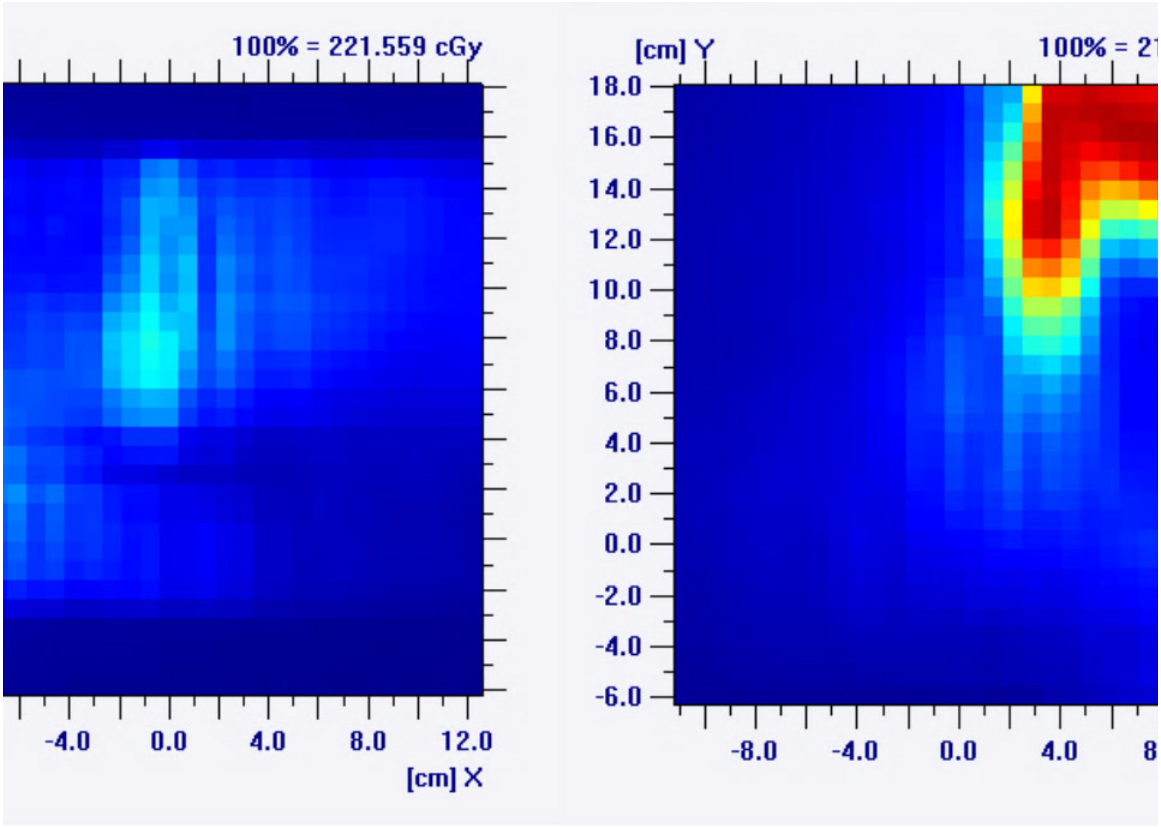


Figure 9 Example case for original position plan that dose distribution was out of the active area of MatriXX.

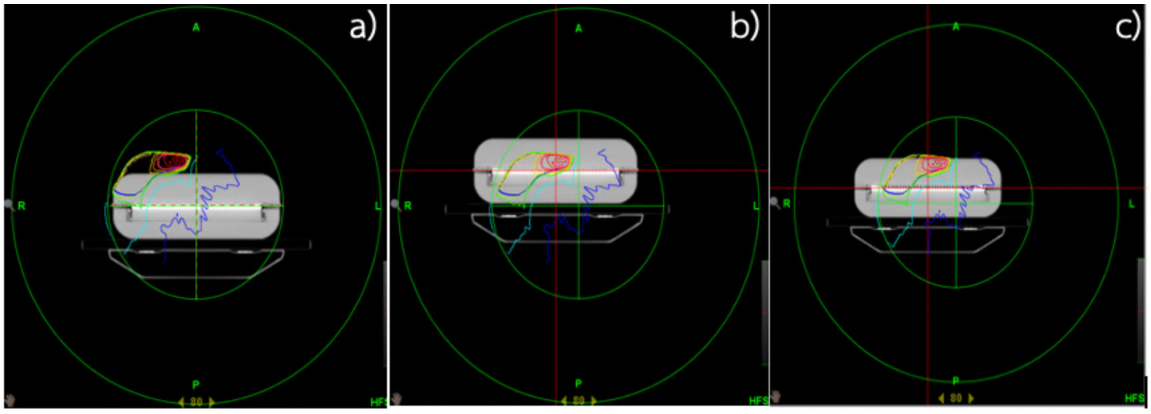


Figure 10 a) The original position plan without a phantom moving, b) Phantom moved in an upper direction more than 6 cm and c) The new DQA plan to shift the phantom by 3 cm.

PSQA in clinical cases with a large radiation field should be concerned. In addition, the gamma criteria should be adjusted for a large field size such as 5%/5 mm , 5%/3 mm, or 4%/4 mm as the suggestion of International Commission on Radiation Units and Measurements (ICRU) no.83 report[24], Atiq et al.[26], and Day et al.[25] However, this study assessed a small sample group of breast cancer, the other factor effect such as plan parameter that had to be adjusted for more complicated anatomy including a large group of sample cases should be investigated to improve the efficiency of using MatriXX detector. Nevertheless, for all extensive tests performed by MatriXX with a miniPhantom for the Tomotherapy HDATM system in this study indicated that the MatriXX was an effective and reliable dosimeter tool and it could be used for patient- specific QA.

Conclusion

Our results showed that MatriXX had a good dosimetric characteristics, including independent of the routine clinically modulation factor, pitch, and field width. The GP of MatriXX measurement for ten prostate cancers passed the criteria following AAPM TG-148 including provided a positive moderate correlation with EBT3 film. Although location moving had no impact on the MatriXX response, the covering of dose distribution and high dose gradient shift should be considered for PSQA of breast cancer using MatiXX. However, the breast case was located out of the axis and had a large radiation field. While the MatriXX detector had a small effective field size and electronic part that to be aware. For this reason, the use of MatriXX for PSQA in clinical cases with a large radiation field should be concerned. Furthermore, the larger sample

group of clinical breast cases with various PTV size and the other factor effect for breast cancer should be investigated to improve the understanding of using MatriXX in Tomotherapy. Nevertheless, for all extensive tests performed by MatriXX with a miniPhantom for the Tomotherapy HDATM system in this study indicated that the MatriXX was an effective and reliable dosimeter tool and it could be used for patient-specific QA.

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