Verification of Radiation Isocenter on Linac Beam 6 MV using Computed Radiography

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Verification of Radiation Isocenter on Linac Beam 6 MV using Computed Radiography

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Abstract. Radiation isocenter is more important part of quality assurance for the linear accelerator (Linac) due to radiation isocenter is a main location in irradiation radiotherapy, isocenter can shift when the gantry and collimator rotation. In general, the radiation isocenter verification using a special film. This research was conducted radiation isocenter verification using computed radiography with digital image processing techniques. Image acquisition was done using the modalities of Linac 6 MV with star shot method is star-shaped beam due to rotation of the collimator, gantry and couch. Then do the delineation on each beam to determine the centroid and beam diameter. By the results of verification of radiation isocenter performed on collimator and the couch, it shows that the size diameter for rotational collimator is 0.632 mm and 0.458 mm for the couch. Based on AAPM report 40 about the size of the Linac radiation isocenter diameter used in this study is still in good condition and worth to be operated because the value of the radiation isocenter diameter is below 2 mm.

1. Introduction

The use of ionizing radiation for the treatment (radiotherapy) of cancer due to interaction of ionizing radiation with tissue can lead to death of cell, either direct or indirect. This is the base of radiotherapy. Radiotherapy utilize the sensitivity of cancer cells, which half of cancer cells get more sensitiv than normal cells, therefore radiation therapy is a cancer treatment method that is commonly used for this [1]. One of the modality of modern radiotherapy used in the treatment of cancer is a Linear Accelerator (Linac). This radiotherapy modality produces electron beam and X-rays (photons) generated by the generator and have the energy that can be varied [2].

Quality Assurance (QA) plays a very important role in ensuring that the treatment given to patients have been correctly conducted. Modern treatment techniques such as Three-Dimensional Conformal Radiotherapy (3DCRT), Intensity Modulated Radiation Therapy (IMRT) and Streotatic Radio Surgery (SRS) aims to deliver maximum radiation dose to the cancer cells and the minimum radiation dose to the surrounding normal tissue. Therefore, various QA tests should be conducted on Linear Accelerator for ensuring accurate treatment delivery [3].

The success of radiotherapy depends on various factors, one of them is the accuracy of the location of irradiation on the planning to the implementation of performed irradiation. Verification radiation isocenter has a very important role on the quality of radiation therapy administered [4].

Radiation isocenter is a very fundamental part of commissioning and QA testing because isocenter Linac is a major role of irradiating radiotherapy [5].

The main reason for the lack of commitment to QA by many hospitals are financial problems. An adequate QA program requires an increase in staff and the latest equipment, both require substantial funds. According to an analysis by Peters, the total cost of radiotherapy QA program about 3% of annual hospital bill [6]. Computed radiography (CR) was first used in the late 80s as a portal imaging with X-rays megavolt energy. CR has several advantages in radiotherapy because it can save operating costs compared to the use of film and Electronic Portal Imaging Device or EPID. In addition, the film storage can affect the outcome of radiotherapy QA. One of QA should be done on Linac in radiotherapy, the radiation isocenter verification. Verification of radiation isocenter generally performed only once when commissioning data collection for the first Linac activated by the Linac vendor. Based Task Group 40 American Association of Physicists in Medicine (AAPM), radiation isocenter verification must be regularly performed once a year so that the research expected of medical physicists can radiation isocenter verification regularly once a year. Verify isocenter radiation aimed to determine linac beam diameter. From the results of research conducted by the Peace of An experimental study on using a diagnostic computed radiography system as a quality assurance tool in radiotherapy showed a maximum variation values between film and CR that is -0.13 mm to verify the radiation isocenter so that CR can be used for QA in radiotherapy [3]. In this research, the authors were done radiation isocenter diameter measurement Linac beam using computed radiography. Radiation isocenter diameter measurement generally used a special film, but it takes a long time in data processing. In this research using CR for easier and faster to display the results of images and data processing.

In the radiotherapy modern treatment, equipment got to be very accurate, that the provision of radiation therapy mostly uses mechanical of collimator, gantry, and an couch that aims to optimize the target range and minimize exposure of surrounding healthy tissue [7]. Based on Task Group 40 American Association of Physicists in Medicine (AAPM) about verification of radiation isocenter conducted once a year [8]. provides recommendations tolerance limit radiation isocenter which is 2 mm, because the radiation isocenter can be shifted during the gantry and collimator rotation [9]. Therefore it is necessary to verify the radiation isocenter on the X-ray beam plane of 6 MV linear accelerator using computed radiography.

2. Literature Study

2.1. Linear Accelerator

Linear accelerator uses electromagnetic waves with high frequency to accelerate charged particles like electrons to produce energy that is directed in a tube linear. Produced high energy electrons can be used directly for the treatment of tumors close to the surface, or directed towards a target that generates X-rays with high energy (megavolt) used for the treatment of tumors in high depth.

For generating a photon beam (X-ray), the high-energy electron beam is passed at a target made of a thin heavy metal so that the interaction Bremstrahlung happens. Bremstrahlung is the X-rays emitted when an electron at high speed passes with a nucleus (nuclei), then the strong Coulomb attractive force causes the electrons to sharply deviate from the initial trajectory [10].

The result of the generation of X-rays have a high intensity in the direction of the target axis. To achieve required flatness, flattening filter made of steel is mounted.

2.2. Definition and Basic Principles of Computed Radiography (CR)

Computed radiography is the digitization of images using a sheet or photostimulable plate for the acquisition of image data [13]. Photostimulable plate on computed radiography stores latent image which is processed by using a laser and can be applied to analog cassette-based screens and films [11].

Principles of pictures imaging on CR is not much different from the conventional radiography, fundamental differences in CR that it does not use screens and films, but it use imaging plate. In the

imaging plate, Photostimulable Phosphor Plate with a thickness of less than 1 mm. Photostimulable phosphorus will capture signals attenuation of X-rays.

The process of imaging on CR begins when the Imaging Plate (IP) is exposed with X-rays, so it will produce a latent image. Exposed IP is inserted into the slot on Imaging Plate Reader Device. Then, IP is scanned with a helium-neon laser (emission of red light with a wavelength of 633 nM) so that, the crystal on the IP produce blue-violet light (wavelength 390-400 nM). This light is detected by the photo sensor and sent via Analog Digital Converter to a computer for processing. After the image is obtained, the IP is transferred to another section of the Imaging Plate Reader Device to remove the remnants of the image to a reusable IP [12].

Imaging plate that has been exposed is inserted into the imaging plate reader. In the IP Reader, the cassette will automatically open, and the IP is taken out. IP is scanned, removed and returned to the cassette to be used for further examination. The image that has been scanned is inputted into a computer for processing and displayed on a monitor or a film.

The most important components in the acquisition of image data consisting of imaging plates, cassettes, and imaging plate reader. Imaging plate is a sheet that can capture and store latent X-ray shadow which the shadow of the latent is formed on the film when the X-rays passing through the patient and captured by the detector. Image acquisition functions performed by Photostimulable Plate or Imaging Plate (IP) is a radiographic film. This IP receives X-ray beam that has passed through the patient's body [13]. As for the characteristics of imaging plate is shown in Figure 1.

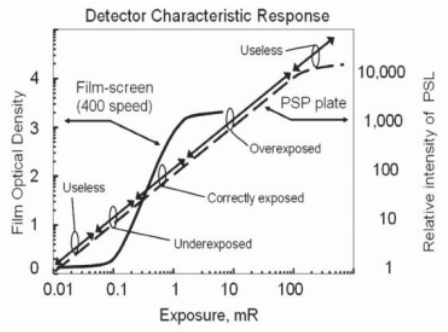


Figure 1. Characteristics of imaging plate [14]

Figure 1 Characteristics of imaging plate is a chart of comparing response screen the movie speed rare-earth 400 (S shaped curve) with photostimulable phosphor in computed radiography (curved dotted lines). Doubled arrow line indicates used exposure divided into underexposed, proper exposure and over exposure regions. Useless area is an area where the given response generating the diagnosis information low value dueto quantum noise and saturation PSP. From the chart, it can be seen that the PSP on CR requires higher exposure, but provides dynamic a widerrange. The wider the dynamic range, the wider the given exposure range CR.

2.3. QA for Linear Accelerator

AAPM report No. 46 discussing the report of the Task Rroup 40 radiation therapy committee: a comprehensive QA for radioation oncology describes the use of linear accelerator that at that time the radiation treatment is the most widely used which would require greater scrutiny and more careful review of the QA test parameters. In addition, a new generation of linear accelerator has been controlled by a computer so that adds to the complexity of tool parameters based on the frequency of measurements, including the parameters described in AAPM Report 13 and some additional parameters that correspond to hardware latest generation [8].

Since the publication of TG-40, several new technologies have been developed and now commonly used in clinical treatment of radiotherapy, named multileaf collimation (MLC), asymmetric jaws, dynamic and virtual wedges, electronic portal imaging devices (EPIDs) and image guidance devices cone-beam CT (CBCT). In addition, TG-40 does not considerate the radiotherapy treatment procedure using stereotactic radiosurgery (SRS), streotactic body radiation therapy (SBRT), total body photon irradiation (TBI), and intensity-modulated radiotherapy treatment (IMRT). So that, AAPM Task Group 142 report: quality assurance of medical accelerator on the latest QA of use Linac is made [15]. This is comparison table of QA TG 40 and TG 142. As for the QA Linear Accelerator is shown in Table 1.

Table 1. QA Linear Accelerator

Frequency	Procedure	Tolerance TG 40	Tolerance TG142
Annual	Mechanical checks		
	Collimator rotation isocenter	2 mm diameter	-
	Gantry rotation isocenter	2 mm diameter	-
	Couch rotation isocenter	2 mm diameter	-
	Coincidence of collimetry, gantry, couch axes with isocenter	2 mm diameter	-
	Coincidence of radiation and mechanical isocenter	2 mm diameter	2 mm from baseline

2.4. Verification of Radiation Isocenter

Verification of radiation isocenter is a very fundamental part of the test of commissioning and QA, isocenter is very important in the treatment of radiotherapy using a Linac as a center of irradiation radiotherapy. Isocenter QA radiation in radiotherapy Linac is a star shot method [5]. As for the radiation isocenter star shot method is shown in Figure 2.

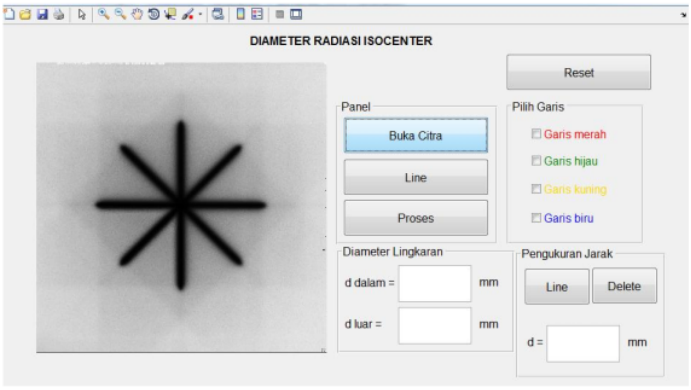


Figure 2. Radiation isocenter star shot method

A stellar beam shots is obtained by placing the film radiation in the field of rotational motion of a gantry, collimator, and an couch. Film will be exposed to radiation from different angles of rotation so that the beam intersect to form stars. radiation isocenter Verify is done by determining the smallest circle of the intersection of all the files, with the center of the circle called radiation isocenter and the radius of the circle called the size of the radiation isocenter. To determine shifts radiation isocenter can

be seen from the result of the file to the isocenter alignment shifting or used laser Linac for determining the location of irradiation [7]

3. Method

3.1. Instruments and Materials

This research use Linac modality with 6 MV photon energy. Then, it uses computed radiography (CR) and the Matlab r2015b. Used Digital image is an image with the TIFF format CR result of the acquisition modalities. This digital image is used as an inputted image that will be processed through the computational programming. The variables in this study is rotational collimator, the angle of rotation and the couch.

3.2. Procedure

Before the study began, firstly research preparation is conducted to ensure QA of Linac output in a constant state during the study by conducting a check output of output daily. Examination results is compared with the results of commissioning according to AAPM recommendations to the deviation of daily output that may not have a deviation of more than 3% compared to the commissioning. In addition, the calibration on the CR is done before being used in research. CR is calibrated by using Linac irradiation at a distance of 100 cm between the Linac tube to the CR plate and the field size of 5 x 5 cm^2 by placing phantom above CR plate. Exposure is done by varying the monitor unit (MU) from 0.5 to 2.5. Then the results were analyzed and obtained a calibration graph the relationship between pixel-dose radiation. As for the schematic of CR calibration is shown in Figure 3.

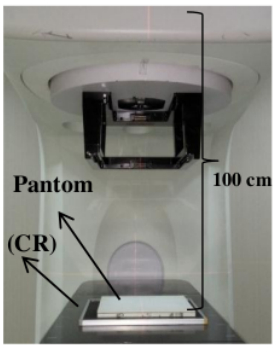


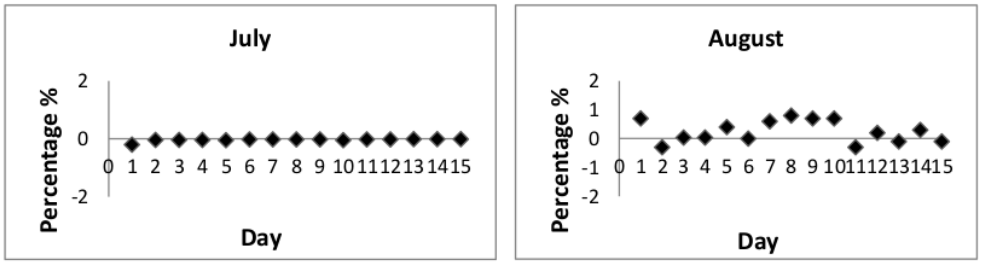
Figure 3. Schematic of CR calibration

Measurement radiation field size is determined on in-line and cross-line axis. Measurement of irradiation on CR cassette with the distance of 100 cm between the tubes air against the CR cassette by using 2 MU exposure, field size of 5 x 5 cm^2. Analysis of measurement data are treated in a plot on the profile beam and determined Full Width at Half Maximum (FWHM) using matlab. Verification of radiation isocenter is conducted using the method of star pattern image to determine the size of the diameter of the radiation isocenter component parameters that are collimator and couch. CR is placed perpendicular to the central axis of X-ray beam. Irradiation is done with the distance of 100 cm between the device tube to the CR cassette. Jaws is opened with the area of 0.2 x 20 cm^2 field for verification of radiation isocenter on used angle collimator were 0, 45, 90 and 135 while on the couch angles used 270, 315, 0 and 45. Then CR is irradiated with a beam energy of 0.5 MU. the results Analysis of the CR image processed by using Matlab with delineation method was done to determine the diameter size of the radiation isocenter.

4. Results

4.1. Linac Calibration Test

Calibration on the Linac, according to AAPM TG 142, includes several timing parameters such as daily, monthly and yearly with calibration testing which is dosimeter parts, mechanical and safety. In this research, calibration test of the X-ray output consistency is done. The percentage output of the X-ray photons in July and August 2016 is shown in Figure 4.



(a) (b)

Figure 4. Percentage output of the X-ray photons in:
(a) July (b) August

By the results on the last two months show output variation device is different for each month. By the pictures, we can observe that Linac output is varies in July with a range between -0.02% to -0.2%, range between 0.8% to -0.3% in August. According to this result, the Linac is still in good condition because it came under the range of -3% to 3%.

4.2. Computed Radiography Calibration Test

CR calibration test by making relationship graph between the pixel value and monitor unit value. CR calibration test using photon irradiation with energy variation start from 0.5 up to 2.5 MU (or in a dose of 0.5 cGy up to 2.5 cGy). As for the computed radiography calibration test results shown in Figure 5.

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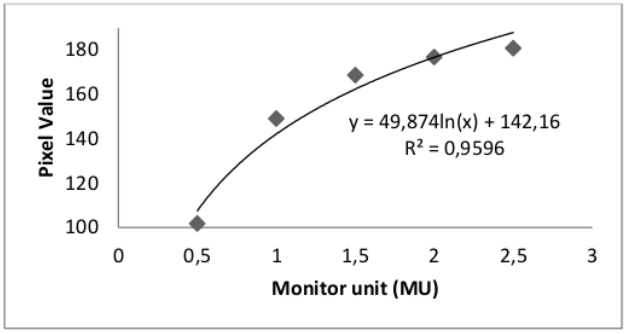

Figure 5. Computed radiography calibration test results

From the computed radiography calibration test results shown in Figure 5 looks the same as AAPM report 93 result about computed radiography responses in the Figure 1 increased over radiation exposure, and then it can determine exposure dose using graph equation above.

The increase in pixel value with increasing radiation exposure relationship with a dynamic range which is ratio of largest and smallest intensity from input photon beam that can be imaged. The smallest intensity affected by noise system. To avoid the system noise affected, so dynamic range should be greater than system noise. While the greatest intensity influenced by receptor saturation. In computed radiography response graph (Figure 1), output of phosphor photostimulable light comparable with exposure.

4.3. Measurements Linac Area Field

Measurements carried out with area of the field of 5 x 5 cm^2, which is irradiated with an energy 2 MU. The measurement results are determined using the FWHM on cross-plane and in-plane axis of the photon beam. The results of irradiation field size measurement are shown in Table 2.

Table 2. Results of irradiation field size measurement

Irradiation field (cm^2)	Irradiation field size measurement			
	Cross-plane	Relativ error	In-plane	Relative error
5 x 5	6.6	0.32	6.6	0.32

Table 2 shows the results of irradiation field size measurement by using a CR with results of error value in 0.32 cross-plane and 0.32 in-plane field Also, it looks the response CR is good enough to used field size form.

4.4. *Imaging Analysis of LINAC beam using CR*

CR imaging analysis produced by beam of LINAC done to verified radiation isocenter by relating Signal to Noise Ratio with chosen Monitor Unit. Analysis done to evaluate quality of CR image in order to get reference image.

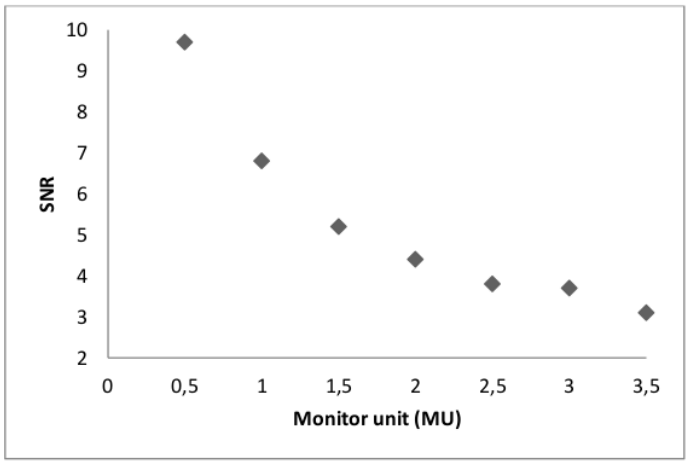

Figure 6. SNR related to MU value

Based on graphic obtained that SNR is changed along with MU value, 0.5 MU is chosen as research parameter which has higher SNR which produce lower image noise [14].

4.4. Verification of Radiation Isocenter Linac Beam 6 MV

Verification of radiation isocenter is performed by using *star shot* which the radiation beam shaped a star due to the rotation of one of the Linac component, the collimator and the couch. To determine the diameter of the radiation isocenter, image processing using Matlab 2015b was done. As for the results of verification of radiation isocenter on collimator and couch are shown in Figure 7.

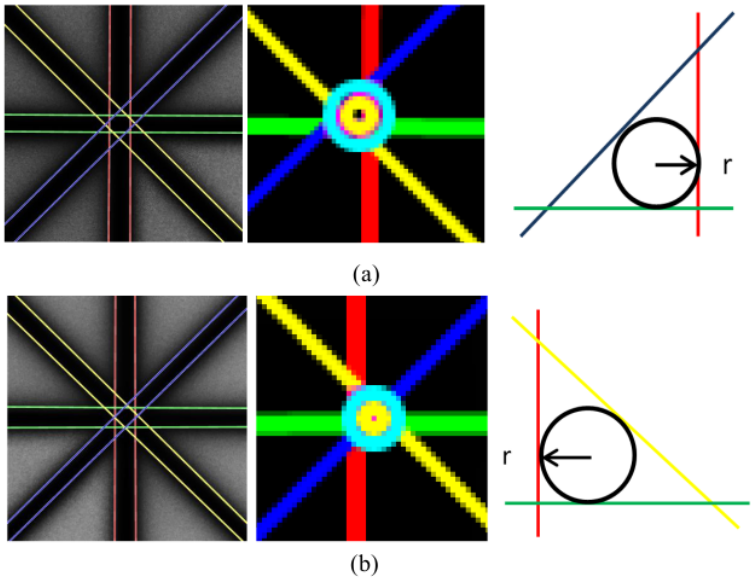

Figure 7. Results of verification of radiation isocenter (a) collimator (b) couch

Table 3. Verification of radiation isocenter on Linac

Rotation Angle	Diameter (mm)	Mean	Standar Deviasi
Collimator : 0, 45, 90, 135	0.632	0.595	0.13
Couch : 270, 315, 0, 45	0.458	0.472	0.03

Determination of radiation isocenter diameter on Linac is very important and will have an impact on the quality og radiation therapy given to patients. Most of the radiotherapy treatment appropriation using a gantry combination, collimator, and couch. For the Linac, radiation isocenter value measurement is not very significant. The results of verification of radiation isocenter are shown in Table 3. performed on a collimator with rotation angle of 0, 45, 90, 135 obtained radiation isocenter diameter that is 0.632 mm and on the couch with an angle of 270, 315, 0, 45 obtained radiation isocenter diameter that is 0.458 mm. But these results have consequences that shape radiation isocenter diameter cause enlargement of penumbra or increase radiation dose on irradiation field shape, especially small field sizes. This can happen because of asymmetry and instability of the tools used. Based on the use Linac for radiotherapy irradiation, collimator is more often used for irradiation method on every patient is different. AAPM report 40 about radiation isocenter diameter Linac size used in this research is still good condition and worth to be operated because that value of radiation isocenter diameter below 2 mm.

5. Conclusions

By the results of verification of radiation isocenter performed on collimator and the couch, it shows that the size of radiation isocenter diameter for collimator is 0.632 mm and 0.458 mm for the couch. Based on AAPM report 40 about the size of the Linac radiation isocenter diameter used in this research is still in good condition and worth to be operated because the value of the radiation isocenter diameter is below 2 mm.

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