Source to Skin Distance (SSD) Characteristics from Varian CX Linear Accelerator

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Abstract. This study aims to describe the characteristics of the source to skin distance (SSD) of Varian CX linear accelerator (LINAC) using the X-ray beam of 6 MV and 10 MV. The variation of the source to the SSD are 90, 100 and 110 cm; the depth of the water phantom used are 5, 10, 15, 20, and 25 cm, respectively. The depth of the water phantom was created for analysis of percentage depth dose (PDD) and profile dose. It can be concluded from the tests that from the measured SSD, SSD of 110 cm with the depth water phantom of 20-25 cm for energy beam of 6 MV and at all levels of depth for 10 MV energy corresponding tolerance limits to be used in clinical radiotherapy. For the SSD 90 and 100, the values beam symmetry and flatness obtained slightly beyond the limits of tolerance.

1. Introduction
Source to skin distance (SSD) is almost used as an important reference to examine the depth of an x-ray in radiotherapist treatment [1]. The aim of this study is to characterize and to measure the dosimetric output of 6 and 10 MV Varian Clinac CX linear accelerator using the variation of SSD. Varian Clinac CX linear accelerator is a very popular linac in Indonesian hospitals. The measurement of output was conducted using devices with ion chambers. Linac used a multi-high energy beam of electrons and photons, the electron with the energy range of 4-22 MeV for the purpose of radiotherapy and the energy range of 6-18 MV for photons. Since the nature of ionizing radiation can damage tissue, then the radiation dose given to the tumor cells must be distributed uniformly or homogeneously in accordance with the rules ICRU that the maximum dose in the range of 95% - 107% [2, 3]. Therapy planning and delivery of the appropriate dose will determine the success of treatment. The maximum dose values for photons do not come on the surface of the skin but is at a certain depth called the maximum depth dose (dmax). The value of dmax depends on the energy of the primary photon. The area between the surface and the maximum depth is known as the build-up. Linac uses high-frequency electromagnetic waves to accelerate the electrons into a high energy through a linear and conductive tube which contains an array of cells form cavities made of copper [4]. We performed in this study a complete description of the characteristics of the SSD of Varian CX linear accelerator (LINAC) using the X-ray beam of 6 MV and 10 MV.
2. Material and Methods

The measurements were conducted using Varian Clinac CX (Varian Oncology, Palo Alto, Ca) at Hasanuddin University Hospital. The procedures of the dosimetric measurements follow a few steps. A phantom containing distilled water was set up and water phantom placed and positioned parallel to the laser position. Position each side of the water phantom was positioned at the same level. The ionization chamber was put in a water phantom and the ionization chamber was connected with an Omni-Pro software on a computer via an optical cable. The irradiation field area was set 10 x 10 cm.

Later, the SSD was set at a distance of 90 cm and the energy 6 MV. The depth of the ionization chamber in a water phantom was positioned with a depth of 5 cm from the surface of the water. The beam focus would set on and PDD and dose profile would be analyzed using the Omni-Pro software. The procedure would be repeated by adjusting the SSD, energy, and depth.

The variations of SSD was 90, 100, and 110 cm. the depth of the water phantom was 5, 10, 15, 20, and 25 cms. The depth of the water phantom was created for analysis of percentage depth dose (PDD) and profile dose. Radiation dose profile characteristics of the radiation beam and provide important information for planning radiotherapy. Dose profile also declared a curve showing the form of face-rays on the horizontal axis that is perpendicular to the direction of x-rays. That curve interprets the distribution of radiation dose relatively on a particular radiation field. Percentage depth dose is the absorbed dose is given on the main depth as a percentage of absorbed dose at the depth of the pointer on the main axis of the area. Dose distribution at the point in the main axis of the files inside phantom usually normalized to $D_{\text{max}}$, as 100% at a depth of maximum dose, $D_{\text{max}}$ corresponding to the reference depth. Value percentage depth dose can be defined as a result, in the form of a percentage, the dose absorbed at a certain depth where is a depth $d$, $d_0$ is the reference dose along the beam axis. The percentage depth dose (PDD) is defined as:

$$PDD = \frac{D_d}{D_{d_0}} \times 100\%$$

(1)
where $D_d$ and $D_{d0}$ are the doses at a depth $d$ and $d_0$, respectively. In use, the peak dose absorbed at a central axis referred to as the maximum dose, $D_{\text{max}}$, is:

$$D_{\text{max}} = \frac{D_d}{P_{dd}} \times 100\%$$

(2)

percentage depth dose for X-rays decreases with increasing depth as the maximum dose is achieved.

3. Results and Discussion

PDD and dose profile measurement is done by using energy X-ray beam 6 MV and 10 MV with a variety of SSD and depth, while the width of the irradiation field is constant (10x10 cm$^2$). All of the measurement method using a water phantom and the ionization detector chamber. Based on figures (3-4) obtained the results of the comparison PDD can be observed in table 1. The value of symmetry and flatness of the dose profile can be obtained in the figures (2-3).

![Figure 2](image1)

**Figure 2.** Percent Depth Dose (PDD) of X-ray beam 6 MV for SSD 90, 100, and 110 cms at a depth of 5, 10, 15, 20 and 25 cms, respectively.

![Figure 3](image2)

**Figure 3.** Percent Depth Dose (PDD) of X-ray beam 10 MV for SSD 90, 100, and 110 cms at a depth of 5, 10, 15, 20 and 25 cms, respectively.
Table 1. Comparison of Percent Depth Dose in the SSD 90, 100 and 110, respectively to the energies of 6 MV X-rays in varying degrees of depth.

| SSD (cm) | Depth | Relative Dose (%) | Reference Dose (%) |
|----------|-------|-------------------|--------------------|
| 90       | 1.28  | 100               | 1.38               |
| 100      | 1.28  | 100               | 1.58               |
| 110      | 1.58  | 100               | 1.78               |

D₀ is an area starting from the center point (medium surface) up to the point where it can be absorbed dose maximum. From all SSD it can be seen, that the dose absorbed in the area will increase until maximum. The higher energy it was given, the longer distance would be required to reach it. Then, after passing through the maximum point, the absorbed dose would decrease with increasing depth.

Beam symmetry depicted in figure 5 and figure 6 showed dose conformity profile area between left and right. While the flatness indicates the maximum dose value and the value of the minimum dose at every level depth. Beam symmetry and flatness value obtained from these figures is determined by the value of SSD. The greater the energy, SSD, and depth are used, the smaller the value of symmetry and flatness obtained. The asymmetry was determined as less than 2% over 80% over all of the field sizes. Using PC Program ion chamber, the maximum asymmetry measured more than 75% of any field for a 40x40 cm field size.

From all the SSD for 6 MV and 10 MV energy beams, the value of symmetry in the SSD 90 in general, is the largest depth, then SSD 100, and the smallest is SSD 110. None of this SSD reached the value of symmetry with the ideal value 0%. Only SSD 110 was still within tolerable limits (S <2%), which is at a depth of 20 and 25 cm for 6 MV beam of energy, whereas for the 10 MV beam of energy to meet the standards of tolerance for all levels of depth used. This indicates that there is an imbalance between the regional distribution of doses left and right areas, this can be seen in figures 4 and figure 5.

Figure 4. Graph of beam profile for 6 MV beam for SSD 90 cm at a depth of 5 to 25 cm.
Figure 5. Graph of beam profile for 10 MV dose for SSD 90 cm at a depth of 5 to 25 cm.

Similarly, for the beam symmetry, none of the SSD reached the ideal value of flatness. For SSD 90 with X-ray energy beam of 6 MV and 10 MV, the average value of flatness is high enough. Only at a depth of 25 cm for X-ray energy 6 MV and at a depth of 20 to 25 cm for X-ray energy 10 MV that remain within tolerable limits (less than 3%). This is due to the distance between the energy source and the surface of the medium (SSD) which is too close. It results in flatness value that approaches the ideal value as it was away from the depth of the surface. For the SSD 100 and 110 for both energy level has a flatness values which are within tolerance at every level of depth.

4. Conclusion
We have measured the dosimetric parameter of the 6-MV X-Ray beams from Varian Clinac CX linear accelerator and compared with other linear accelerators. The SSD characteristics of Varian Clinac CX are similar and allowed to be used in regular clinical radiotherapy. From the three measured SSD, only SSD 110 with the depth of 20 - 25 cm for energy beam of 6 MV and at all levels of depth for 10 MV energy corresponding tolerance limits, which is feasible for use. For the SSD 90 and 100, the values beam symmetry and flatness values obtained slightly beyond the limits of tolerance.

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