Comparison of absorbed dose distribution 10 MV photon beam on water phantom using Monte Carlo method and Analytical Anisotropic Algorithm

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Abstract. Treatment planning is a process of radiation therapy performed by medical physicists in the hospital. This process can be understood as a simulation to determine parameters such as photon energy, field size, and the absorbable dose to be received by the patient. Simulation treatment planning is usually done using TPS ECLIPSE with AAA or Acuros XB method that has been integrated into it. In this research, the comparison of the distribution of absorbent dose of 10 MV photon at water phantom using Monte Carlo-EGSnrc and AAA-ECLIPSE method was used. Monte Carlo simulations were performed with 6x6 cm², 10x10 cm², and 20x20 cm² field size variations and initial electron energy variations 10.1 MeV, 10.2 MeV, 10.3 MeV and 10.4 MeV. The design and simulation of Linac heads are done using BEAMnrc and the calculation of absorbent doses in this water phantom using DOSXYZnrc. The BEAMnrc simulated particle information was analyzed using BEAMDP. To obtain the depth dose distribution or PDD and PROFILE the dose is done using stdose code. Based on the data processing, the result shows that the mean deviation of PDD and D max from the three field sizes is 7.09% for 10.1 MeV, 2.71% for 10.2 MeV, 2.86% for 10.3 MeV and 7.39% for 10.4 MeV. These results indicate that the initial electron energy has the least deviation of 10.2 MeV. As for the dose profile in the field size 10x10 cm² obtained deviation 6.65% to 10.2 MeV

1. Introduction

Treatment planning system is a process of radiation therapy planning performed by medical physicists in the hospital. This process can be understood as a simulation to determine physical parameters such as photon energy, field size and absorption dose to be accepted by patients using Analytical Anisotropic Algorithm (AAA) and Acuros XB algorithms integrated with the Eclipse Varian Medical System TPS system. AAA is a dose calculation algorithm divided into two processes namely configuration and dosage calculation, the configuration is a process to determine the physical parameters such as photon energy, field size, and absorption dose to be accepted by patients.
parameters that can be used to obtain fluence characteristics and photon energy spectrum, this physical parameter has been previously calculated using Monte Carlo then modified in order According to clinical data, this continues throughout the configuration process and all parameters of the configuration results will be used for dose calculations, while dosing of AAA algorithm based on primary photons, extra-focal photons, electron contamination and photon scattering are all incorporated in a beamlet ) [1]. Nowadays, AAA algorithm development has been developed, AAA and Pencil beam Convolution (PBC) evaluation in the case of water-lung phantom [2], comparison of dose distribution on small size phantom using AAA and Monte Carlo [3], comparison of dose distribution Using AAA and experiments [4].

Monte Carlo is a method that uses the principle of random numbers, this method is very well used for the simulation of particle interactions that occur in stochastic, very accurate in the calculation of the dose distribution to make Monte Carlo as "gold standard" in the calculation of dose distribution. Previous studies have shown that the deviation of Monte Carlo PDD results and experiments is 1.07% [5], not only to calculate dosage distributions inhomogeneous tissues but also in Monte Carlo's inhomogeneous tissues capable of calculating dose distribution very accurately [6]. In this research, the calculation of dose distribution in this water phantom using Monte Carlo BEAMnrc and DOSXYZnrc simulation which is the development of EGSnrc. BEAMnrc is used to design and simulate the particle interaction on the Linac head Varian, the result is a phase space file containing the interaction particle information and it can be analyzed using BEAMDP. DOSXYZnrc is used to design and simulate the dose distribution in water phantom the result is data of .3ddose which is then analyzed using statdose code. The results of this dose distribution will compare with the dose distribution of AAA simulation results from one of the hospitals in Bandung.

2. Method

2.1. Design and simulation of head Linear Accelerator (Linac)

Material and geometry data specifications for the design of Linac heads were obtained from the Monte Carlo High Energy Varian Clinac iX. The data information is used as input in Monte Carlo simulation on BEAMnrc.

| No. | Component Module                  | CM    |
|-----|-----------------------------------|-------|
| 1   | Primary Collimator+target         | FLATFILT |
| 2   | Vacuum Window                     | FLATFILT |
| 3   | Flattening Filter                 | FLATFILT |
| 4   | Monitor Chamber                   | CHAMBER |
| 5   | Jaws                              | JAWS  |
| 6   | MLC                               | DYNVMLC |
| 7   | Air                               | SLAB  |

Figure 1. (a) Design head Linac, (b) Component module used in BEAMnrc [8]

Figure 1 shows the result of head Linac design using BEAMnrc. Linac modeled is Linac Varian with 10 MV photon beam, variation of field size 6x6 cm², 10x10 cm² and 20x20 cm² and variation of initial electron energy 10.1 MeV, 10.2 MeV, 10.3 MeV and 10.4 MeV. In this process the Linac design is made of two components: Patient-dependent component, using ISOURCE 19 (Elliptical beam with
Gaussian distribution in X and Y) resulting phsp part 1 and Patient-independent components, using
ISOURCE 21 (full phsp beam data, incident on any CM) that produces phsp part 2, this is done to
reduce the simulation time required to use different field size variations. The second phsp is used as
input into DOSXYZnrc.

2.2. Design and simulation of dose distribution
Size of water phantom used is 40x40x40 cm³, made into two design that is for the calculation of the
depth dose and dose profile. The simulation is done in DOSXYZnrc with ISOURCE 2 (full phsp
source file).

| Coord | Num of Voxels | Voxel Size (cm) |
|-------|---------------|-----------------|
| X     | 3             | 18.5            |
|       | 2             | 3               |
|       | 3             | 18.5            |
| Y     | 3             | 18.5            |
|       | 2             | 3               |
|       | 3             | 18.5            |
| Z     | 36            | Group 1 (2 voxel) | 0.4 |
|       |               | Group 2 (16 voxel) | 0.2 |
|       |               | Group 3 (18 voxel) | 2   |

Figure 2. Design water phantom for depth dose calculation [7]

| Coord | Num of Voxels | Voxel Size (cm) |
|-------|---------------|-----------------|
| X     | 3             | 19              |
|       | 2             | 2               |
|       | 3             | 19              |
| Y     | 80            | Group 1 (7 voxel) | 2   |
|       |               | Group 2 (10 voxel) | 0.2 |
|       |               | Group 3 (8 voxel) | 1   |
|       |               | Group 4 (10 voxel) | 0.2 |
|       |               | Group 5 (7 voxel) | 2   |
| Z     | 3             | 9.5             |
|       | 2             | 1               |
|       | 3             | 29.5            |

Figure 3. Design water phantom for dose profile calculation [7]

It can be seen Fig 4. Design of water phantom for depth dose calculation is made the smaller size and
number of voxel on the Z axis, while for dose profile in Y-axis direction at 10 cm depth.
3. Result

Based on data processing, the result of depth dose and dose profile for each variation of initial electron energy and field size, then compared with AAA simulation result. The graphic as follows.

*Figure 4.* (a) (b) (c) Depth dose graph for field size and initial electron energy variation (d) dose profile graph with initial electron energy variation in size field 10x10 cm² and depth 10 cm.

Based on Figure 4 it can be seen that the depth distribution pattern has increased significant doses on the surface of the water phantom until it reaches the maximum depth of dose then undergoes decline as the depth of water phantom increases. This is because the photon beam generated from the Linac are not only composed of photon beams but also composed of an electron and positron particles that have a shorter range than photons so that will interact earlier, electron and positron particle distribution can be seen when performing the analysis Phase space file with BEAMDP. The dose decrease after D_max because the photon interacted by giving energy to the water phantom, more in water phantom the photon energy given will be smaller.
4. Discussion
Based on Figure 4, the initial electron energy of 10.4 MeV produces the smallest depth dose deviation of 1.85% in the 6x6 cm$^2$, 10.1 MeV with deviation 1.57 % on 10x10 cm$^2$ and 10.2 MeV with deviation 0.73 % on 20x20 cm$^2$. While the initial electron energy with a small $D_{\text{max}}$ deviation of 10.1 MeV gives a deviation 3.91 % on 6x6 cm$^2$, 10.2 MeV with deviation 3.60 % on 10x10 cm$^2$ and 10.1 MeV with deviation 5.71 % on 20x20 cm$^2$. To determine the initial electron energy used can be done by looking for the least average deviation of depth dose, $D_{\text{max}}$ and dose profile.

5. Conclusions
The mean deviation of depth dose and $D_{\text{max}}$ from the three field sizes is 7.09% for 10.1 MeV, 2.71% for 10.2 MeV, 2.86% for 10.3 MeV and 7.39% for 10.4 MeV. As for the dose profile in the field size 10x10 cm$^2$ obtained deviation 6.65% with 10.2 MeV. Based on these results it can be concluded that the initial electron energy having the least deviation is 10.2 MeV with the mean deviation 4.02 %.

6. References
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