Quality Assurance Plan for Linear Accelerator (LINAC) on Nasopharynx Cancer (NPC) Treatment at Radiotherapy Installation Ken Saras Hospital

Pandu Kurnianto[1], Giner Maslebu[2*], Jodelin Muninggar[3], Muhammad Hidayatullah[4]

[1,2,3]Physics Department, Faculty of Science and Matematics, Universitas Kristen Satya Wacana, Jl. Diponegoro 52-60, Salatiga, Central Java 50711, Indonesia

[4]Radioteraphy Division, Ken Saras Hospital, Jl. Soekarno Hatta No.km.29, Kebonan, Randugunting, Kec. Bergas, Kabupaten Semarang, Central Java, Indonesia

*giner.maslebu@uksw.edu

Abstract. Radiotherapy is the treatment of cancer by using electromagnetic and particle radiation. Nasopharyngeal Cancer (NPC) is one of the difficult case to be treated in radiotherapy because its anatomical location. Precision of radiation dose is part of Quality Assurance Program as the key factor in this treatment. Thus, it is very important to ensure that the output dose of Linear Accelerator (LINAC) matched with result of Treatment Planning System (TPS). This study used Siemens LINAC Type Primus MACH Series 5633 and a set of detectors for Nasopharynx Cancer analysis with 8 field. The total dose of 5,000 cGy divided into 25 fractions with 200 cGy dose per fraction. The 8 fields are irradiated with a target on a detector device. It is then accumulated with PTW-Verisoft software by plotting the results obtained from the detector tool with PTW (phantom) which we have CT Scanned first in PTW-Verisoft. From the total detectors exposed to the radiation, the detector corresponding to PTW is 372 detectors (100%) with unsuitable detector of 0 detectors (0.00%). It is proved that the planning is 100% match for NPC with 8 fields of radiation. Thus, this method is recomended to be implemented for NPC treatment.

Keywords: Quality Assurance, Treatment Planning System, NPC, Radiotherapy

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1. Introduction

Radiotherapy is the treatment of diseases, especially tumors or malignant cancer by using electromagnetic radiation (X-ray and gamma) and particle radiation (electrons, protons, neutrons). This technique was first discovered in the late 19th century after the discovery of X-rays by W.C. Rontgen, the radioactivity properties by Becquerel, and the discovery of radium by Pierre and Marie Curie. With the rapid advancement of technology, radiation therapy continues to improve and is increasingly popular and commonly used, particularly for cancer treatment[1]. The presence of vital organs affected in this radiation will greatly limit the maximum dose that can be given, especially if the vital organs have a high sensitivity to radiation. In general, external radiation is done by a linear accelerator (LINAC)[2].

The nasopharynx is located near several anatomical structures that are highly sensitive to radiation, including the spinal cord, medulla oblongata, eyes, middle and internal ear, parotid gland, temporal lobes, and hypothalamus-pituitary axis. The nasopharyngeal wall is covered by mucosa with many folds. Histologically, the nasopharyngeal mucosa formed by the pseudostratified ciliated columnar epithelium (pseudostratified ciliated columnar epithelium) toward the oropharynx will be transformed into a stratified squamous epithelium. Between them there is a transitional epithelium primarily obtained on the lateral wall in the Rosenmüller fossa region [3-4].

Nasopharyngeal carcinoma (NPC) is characterized by its rapid infiltration into nearby tissues, resulting in irregular radiation volumes and multiple toxicities to the structures affected by the tumor[4]. It differs in terms of its epidemiology, histology, natural progression, and treatment response. NPC also shows a clear connection to specific races and geographic regions, which indicates that its development is influenced by multiple factors. While NPC is rare in Europe, it is endemic in Southeast Asia[5]. It is a common cancer in Indonesia and is ranked fourth after cervical cancer, breast cancer, skin cancer and is the most common cancer in the head of the neck. This disease is 100% associated with Epstein Bar Virus (EBV), especially undifferentiated carcinoma type. Nearly 60% of malignant head and neck tumors are NFC, followed by nasal and paranasal sinus tumors (18%), larynx (16%), malignant oral tumors, tonsils, thyroid and hypopharynx in lower percentages[6].

Treatment Planning System (TPS) is a radiotherapy plan to determine accurately, selectively, the type of energy and direction of the ray. This system aims to obtain a homogeneous dose of radiation on tumor mass or to avoid critical organs. There are 3 areas in radioteraphy around the target: 1) Gross Tumor Volume (GTV) is part of a palpable tumor, visible to the naked eye, with the help of endoscopy or imaging of plain and contrast radiographs, CT Scan, MRI; 2) Clinical Tumor Volume (CTV) is a GTV plus an area potentially infected by a subclinical tumor; 3) Planning Target Volume (PTV) is a geometric concept defined by clinical and physics (computers, simulators and radiation equipment used). These targets are designed on the basis of data in software to ensure CTV is adequately radiated. Examples of pulmonary heart, breathing or swallowing; 4) The Organ at Risk (OAR) is an organ within the radiation field and can cause treatment and dosing planning changes and as a healthy organ that needs to be protected from radiation exposure[7].

Quality Assurance (QA) is a program designed to control and maintain the quality set for the program. The QA program in general in radiotherapy is important and fundamental. The goal ensures that the results of a software can be predicted correctly, and that every hardware device is used with the correct system function and ensures that quality control procedures are adequate, and applied to individualized therapy planning systems[8]. Several QA studies have been conducted to obtain quality radiotherapy devices, Ehsan has compared 3D Radiotherapy and Intensity Modulated Radiation Therapy (IMRT) techniques in nasopharyngeal cancer patients. Al Hayat's has also compared the distribution of doses to the target and for normal tissue in brain tumors with IMRT and 3D the 3D conclusions can be applied but if PTV is close to OAR then IMRT is preferred [9-10]. Sahoo did research using Linac tools with 6MV photon energy and 10 MeV electrons in a water phantom. The study measured a complete set of data according to Linac's performance and made a comparison of the data used 13 years earlier [11]. Iskandar in his study analyzed the use of wedge in cases of nasopharyngeal cancer. The wedge used

varies from 15^0, 30^0, 45^0, 60^0. The method used is to compare the location of the DVH curve for a particular volume with different wedge usage. The results obtained that the use of wedge 60^0 contribute the largest dose distribution to PTV and a minimum on OAR[12]. Narsakha has also evaluated the stability of the Linac Medic plane by using two Linacs. Mevatron 20 and 12 have been evaluated for month-long stability using the RMI daily constancy tool. The% stability is less than 3% for the electron beam of 7,10,12,15,18 MeV and photon files 15 MV and Vevatron 20[13].

In newly treated nasopharyngeal carcinoma (NPC) patients, stereotactic radiotherapy is used to deliver increased doses to residual lesions after three-dimensional conformal intensity modulated radiotherapy, resulting in better local control and survival rates. However, during the treatment, it is important to protect the carotid sheath to reduce long-term damage to nerves and blood vessels, which can help decrease the likelihood of severe nasopharyngeal hemorrhage [14]. A crucial aspect of radiation therapy treatment clinics is designing a radiation treatment plan with precise and trustworthy dose calculations, which serves as a crucial assessment tool. The accuracy and reliability of the plan depend on the type of dose calculation algorithm utilized by the treatment planning system (TPS). Despite the dose calculation algorithm used, the delivered dose remains consistent; thus, the predicted dose must be precise and reliable across various TPSs[15]. To achieve effective control of the disease in the area being treated and ensure long-term recovery, it is essential to have a precise, careful, and logical approach to defining the treatment target. Additionally, it is important to take proactive measures to protect healthy structures in order to minimize the likelihood and seriousness of complications associated with radiation therapy[16]. To keep up with the constantly evolving complexity of technology and radiotherapy techniques, including IMRT, small fields, 4D applications, etc., it is essential to have practical, accurate, and precise dosimeters and dosimetry systems[17].

Based on the previous studies and the importance of radiation dose analysis in NPC case, thus we need to determine the suitability of radiation dose from TPS with the doses produced by LINAC that will be used for irradiation on NPC by considering around PTV and OARs.

2. Methods

Data collection begins with the manufacture of Treatment Planning on NFC cases with standard planning (8 Fields) taking into account the anatomical aspects: a)The superior limit covers the entire base of the crani including the spenoid sinus; b)The anterior margin is in the middle of the durum palate, including khoanae or 1/3 posterior maxillary sinus; c)The posterior limit should include the posterior lymph node of cervical and all of the soft tissue cervicalis or include the cervical spinosus process.;d)The inferior limit covers all mandibles approximately as high as C2 and C3; e)The dose is given 180-200 cGy per fraction given 5 times a week a week so the dose reaches 66-70 Gy with regard to the radiation field.; f)When the dose reaches 40 Gy, the spinal cord must be removed from the radiation field, meaning the posterior border is advancing anteriorly or anterior to the Meatus Acusticus Externus (MAE). At the same time the superior boundary can be lowered so that the base crani is outside the radiation field. When the dose reaches 50 Gy the inferior border is raised to as high as C2 and the anterior border retreats until it reaches khoanae.; g)Furthermore, radiation in the neck and clavicula Lymph node is done from the anterior direction, the superior limit of 0.5 cm caudad from the nasopharyngeal border.; h)The inferior and lateral limits include the entire fossa of the left and the dextra clavicula, and closure or blocking the middle of the neck to protect the thyroid gland, trachea and spinal cord.;i) The two inferior angles of this field are closed to protect the apex pulmo dextra and sinistra.;

With these aspects, 8 radiations fields were designed for nasopharyngeal cancer irradiation: Supraclavicula (SPCLV), Anteroposterior (AP), 40^0,140^0,320^0,220^0 and lateral 90^0 and 270^0. For supraclavicula lymph node section made SPCLV field with gantry angle 0^0 with block at Trachea area, lung apex and spinal cord. For colli lymph node are made 5 fields is AP angle 0^0 with Trachea block and spinal cord, then 40^0, 140^0, 320^0, 220^0 without block. For the Gross Tumor Volume (GTV) area or primary tumor, the 2nd lateral direction is 90^0 and 270^0. Then the dose distribution can be calculated and

viewed at Dose Volume Histogram (DVH) up to the maximum dose on Planning Target Volume (PTV) and minimum on Organ At Risk (OAR).

TPS can be made appropriate with the needs, for example: the direction of gantry angle, field width (Jaws), collimator, radiation weights, blocks, and isodic curves to see the distribution of doses in certain areas. Then with the same data we apply to phantom as thick as 10 cm that has been in the previous CT Scan. Before the patient performed radiation, first done Quality Assurance Plan against Planning that has been made to know the suitability of radiation dose output tool with planning that has been made. Quality Assurance Plan is done by phantom previously in CT Scan placed on the table of LINAC with the same phantom thickness, and adjusted to laser on LINAC plane. Then carried out irradiation against the phantom. After completion of the process of irradiation against the phantom, done checking (plotting) by using PTW-Verisoft software.

Figure 1. Positioning of Solid Water Phantom and laser marker

Calculating the number of detectors used using equation (1):

$$x(\%) = \frac{x}{TD} \times 100 \qquad (1)$$

X is the number of detectors used and TD is Total Detector. Calculation of the corresponding dose detector using equation (2):

$$y(\%) = \frac{y}{x} \times 100 \qquad (2)$$

Where y is the number of detectors according to the dose. Calculation of non-appropriate dose detector using (3):

$$z(\%) = 100\% - y \qquad (3)$$

Where z is an unsuitable detector dose. The result calculation is obtained by equation (4):

$$result(\%) = \frac{y}{x} \times 100 \qquad (4)$$

3. Results and Discussion

Planning creation is done in TPS room using Prowess Panther 5.10 software. On planning creation is important to check on the PTV and OAR first for determine the radiation dose in each field. This can be seen in the Dose Volume Histogram (DVH). Figure 2 is the relationship or influence of total dose with total volume of target organs (PTV) and OAR. For example target organs (PTV) in light blue graph (target 1), the above picture uses a total dose of 7000 cGy (X axis) and total target volume (Y axis). The conclusion of the figure is on the target organ (PTV) at a total dose of 7000 cGy obtained dose curve

close to 1 or 100% of the target volume (PTV). Like previous exposure, the maximum dose on target organs and minimum in healthy organs. For healthy organ around the nasopharynx can be seen in figure 4 as an example is chiasma nerve, mandible, brainstem, orbita, etc as in the graph in different colours to facilitate the reading. For PTV organs, the maximum limit for over exposure of 2% in the curve indicates a PTV curve that exceeds the line above 7000 cGy.
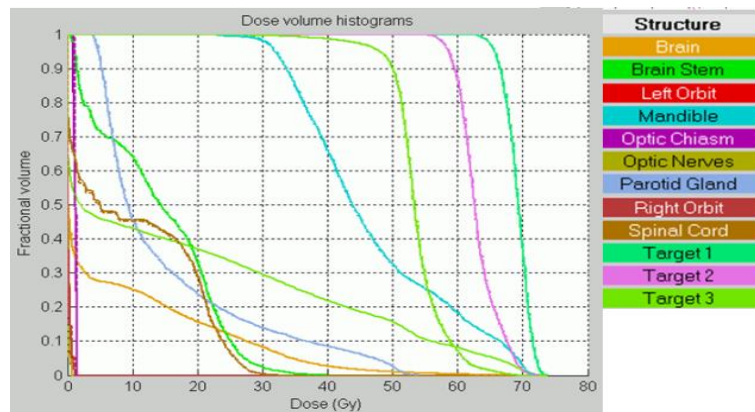

Figure 2. Dose Volume Histogram (DVH) (Primary data)

Matching treatment results with phantom-based simulations to demonstrate the success rate of the QA protocols were performed on each field. For irradiation dose in SPCLV field that is 19.7 cm X 13.6 cm shown in Figure 3a and Figure 3b.
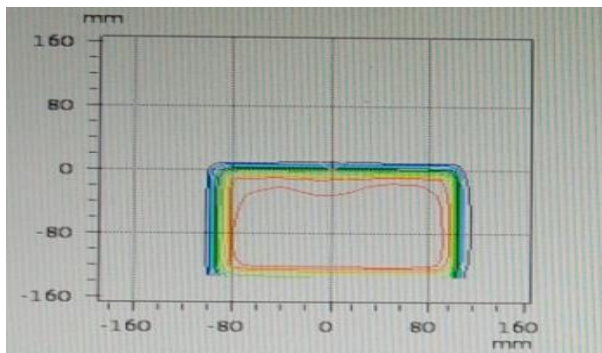

Figure 3a. Result of SPCLV irradiation on detector (Primary data)
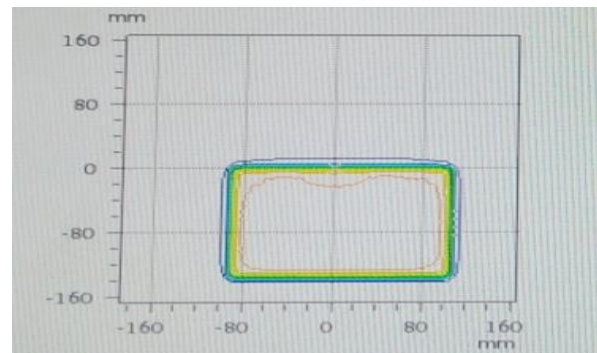
Figure 3b. SPCLV field on phantom (Primary data)

In SPCLV field this is done for irradiation of upper Lymph Node region of clavicle bone where the area is CTV from nasopharyngeal cancer. In that area shows the total detector that is exposed to radiation of 280 detectors, in other words the results corresponding to planning in the SPCLV area are 100% of the total detector that is exposed to radiation.
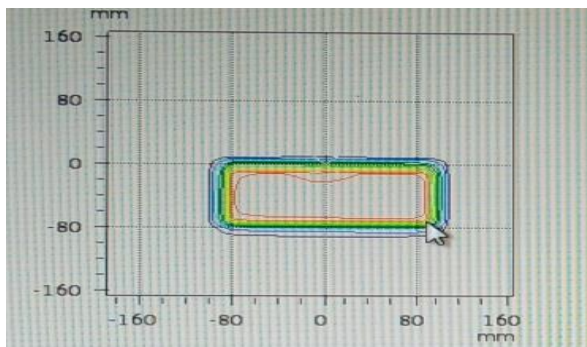
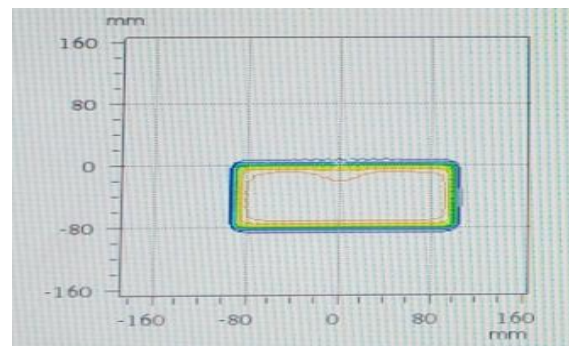**Figure 4a.** AP field on detector (Primary data)

Figure 4b. AP field on phantom (Primary data)

Figure 4a and 4b represent an anteroposterior (AP) irradiation area with the area shined as Coli lymph node. In Coli lymph node, the area is irradiated with 5 fields is AP, 40^0, 140^0, 320^0, 220^0. Especially for AP field, radiation-exposed detector of 176 detectors. Of the 176 detectors, the detector in accordance with the planning is as many as 176 detectors with an AP field of 19 cm X 8 cm. With these data showing the result of dose conformity on the AP field is 100% of the radiation exposed detector. Irradiation in coli region continued and shown the data as follows:

[1] With data on the number of detectors exposed to radiation of 96 detectors. All 96 detectors are in accordance with the planning results. In other words, on the 140^0 field the corresponding detector is 100% with a field area of 10.5 cm X 8 cm;

[2] With the total number of detectors exposed to radiation of 92 detectors. All 92 detectors are in accordance with the results of planning. In other words, on the field of 40^0 detectors corresponding to is 100% with a field size of 10 cm X 8 cm.

[3] With the data the number of detectors that are exposed to radiation as much as 72 detectors. All 72 detectors are in accordance with the results of planning. In other words, on the field 320^0 the corresponding detector is 100% with an area of 8 cm X 8 cm.

[4] With data on the number of detectors exposed to radiation of 68 detectors. All 68 detectors are in accordance with the results of planning. In other words, on the field of 220^0 detectors corresponding is 100% with a field width of 7.4 cm X 8 cm.
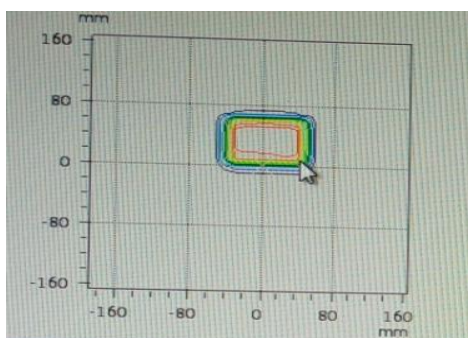

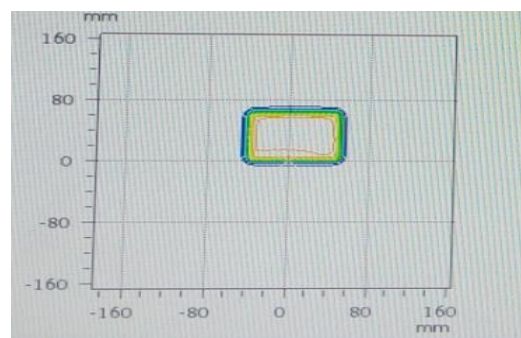**Figure 5a.** 270^0 field on detector (Primary data)

Figure 5b. 270^0 field on phantom (Primary data)

Figure 5a and 5b show the area of exposure to the GTV area or primary cancer. With data on the number of detectors exposed to radiation of 68 detectors. Of the 68 detectors, 67 detectors are in accordance with the planning results, in other words the corresponding 270^0 detector field is 98.5% and the unsuitable one is 1 detector of 68 detectors or 1.5% with the field area of 9.2 cm X 6.4 cm.
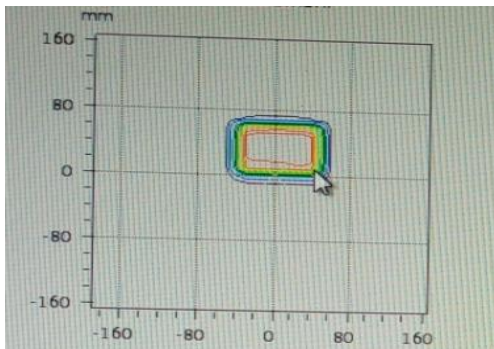
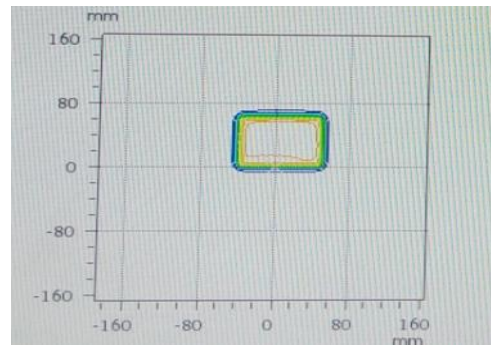**Figure 6a.** 90^0 field on detector (Primary data)

Figure 6b. 90^0 field on phantom (Primary data)

In figure 6a and 6b show the area of irradiation is GTV from nasopharyngeal cancer. With the total number of detectors exposed to radiation of 78 detectors. Of the 78 detectors, 78 detectors are in accordance with the results of planning, in other words on the field the corresponding 90^0 detectors are 100% with a field area of 9.5 cm X 6.8 cm.

The color of the lines on the isodic curve indicates that the area is exposed or has a different dose value. Here is the dose value based on the color ranging from the highest is red with dose distribution 1.1 Gy, yellow 1 Gy, green 0.5 Gy, dark green 0.1 Gy, purple 0.05 Gy. This dose distribution is only used in dosage distribution per field. The incorporation of 8 radiation fields was accumulated into 1 treatment to obtain a complete picture of NFC as shown in Figure 7a and Figure 7b.
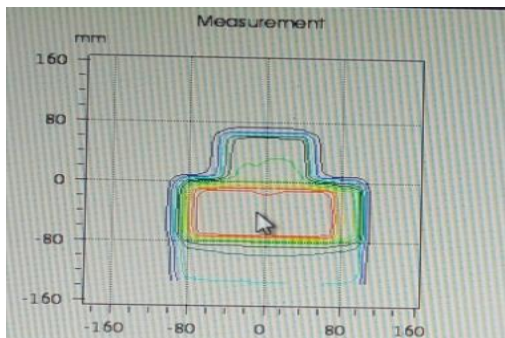

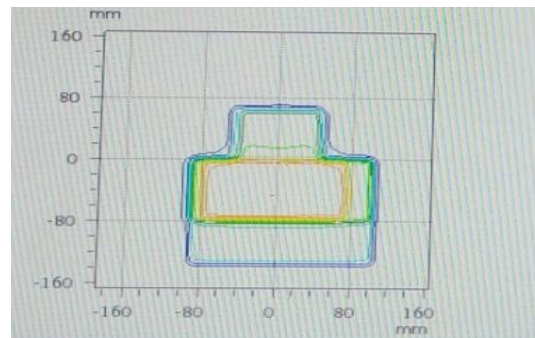**Figure 7a.** 8 fields on detector (Primary data)

Figure 7b. 8 fields on phantom (Primary data)

By using the PTW-Verisoft software, it was found that 372 detected radiation detectors from a total of 729 detectors (51% of the total detectors). 372 of these 372 detectors obtained 372 detectors according to CT Scan calculations (100% of the number of detectors exposed to radiation) and as many as 0 non-matching detectors (0.00%). With the data obtained the conformity of the results 100%. The dark blue color indicates that the detector is not exposed to radiation, light blue indicates the detector is exposed to radiation smaller than the yellow and red green. The colour does not indicate the dose value, but shows the level of distribution of doses to the surrounding area in the lowest order is purple with dose distribution 0.5 Gy, light blue colour with dose distribution 1.5 Gy, green colour with dose distribution 2.3 Gy, yellow colour with dose distribution 3.3 Gy and orange colour with 4 Gy dose distribution. The shape of the image indicates a dilated field area based on the area of the nasopharyngeal field. The dosage distribution is only used in 8 field treatments. The results of the calculation per field and the 8 field are shown in Table 1.

Table 1. Result of irradiation detector per field

Field	Detector used	Dose appropriate Detector	Incorrect Detector	Result

	in number	in percent	in number	in percent		
SPCLV	280	38.4%	280	100%	0(0%)	100%
AP	176	24.1%	176	100%	0(0%)	100%
140	96	13.2%	96	100%	0(0%)	100%
40	92	12.6%	92	100%	0(0%)	100%
320	72	9.9%	72	100%	0(0%)	100%
220	68	9.3%	68	100%	0(0%)	100%
270	68	9.3%	67	98.5%	1(1.5%)	98.5%
90	78	10.7%	78	100%	0(0%)	100%
8 Fields	372	51%	372	100%	0(0%)	100%

From Table 1 above, it appears that the only radiation field whose success rate <100% is at irradiation of 270^0, but at the merging of 8 field success rates to 100%. This is because between the field with each other mutual superposition so it can close the lack on the edge of the field.

4. Conclusions

Comparison between TPS data and direct measurement of irradiation dose has been done using Siemens LINAC Type Primus MACH Series 5633 and a set of detectors for Nasopharynx Cancer analysis with 8 fields radiation plan. All 372 detectors were successfully exposed to radiation source. For per-field plotting results based on data obtained from 8 irradiation fields only one field is found < 100%, at 270^0 field gantry angle (98.5%). The final conclusion of this research is the conformity between planning made and LINAC tool is 100%. It is proved that 8 fields irradiation technique is suitable for NPC treatment in radioteraphy. The future research might include more than 8 fields as the location of Nasopharynx close to many OARs so that we can calculate the accuracy and more precise possibility of dose distribution and treatment.

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