Geometrical Analysis of IMRT/VMAT on Head and Neck Case Using New and Reused Thermoplastic Mask in Dharmais Hospital National Cancer Center Indonesia

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INTRODUCTION

Advanced radiation therapy techniques such as *Intensity Modulated Radiation Therapy* (IMRT) and IMRT *Volumetric Arc Therapy* (VMAT) may offer significant advantages to spare organs at risks in head and neck cancer treatment.[1]. However, its clinical success is limited by its requirement for motion management and reduction of an inter-fractional setup error. [2], [3] In cases where there are many critical organs at risk (OAR) that needs to be spared, such as head and neck cancer cases, certain efforts must be made to ensure accurate positioning of the inter-fraction patient and obtain a repeatable dispensing of the dose, one of those efforts is the use of immobilization device such as a thermoplastic mask.[4], [5]

The challenge for health practitioners, especially in low middle-income countries such as Indonesia is to maintain efficacy as much as possible with minimal operational costs. Considering high operational costs and the recommendation from the thermoplastic mask vendors, some radiotherapy centers still practice reusing thermoplastic masks. Therefore we would like to investigate and ensure the accuracy of new and reused thermoplastic masks and to determine the PTV margin.

OBJECTIVES

This study was conducted to determine :

a) The patient shift during pre-treatment verification using new and reused mask for head and neck cancer patients treated with IMRT/VMAT in our center.

b) Difference in setup displacement for new mask and reused mask for head and neck cancer patients treated with IMRT/VMAT in our center.

c) Systematic and random error value in head and neck cancer patients treated with IMRT/VMAT in our center.

d) PTV margin recommendation for head and neck cancer patients treated with IMRT/VMAT in our center.

e) Recommendation regarding the use of reused thermoplastic masks in our center.

MATERIALS AND METHODS

The experiments were conducted using Varian Trilogy Linear Accelerator and planning were performed using Eclipse Treatment Planning System (TPS). We analyzed systematic and random error calculation in the setup verification of 42 patients with head and neck cancer, treated with IMRT/VMAT from March-June 2019 . Patients included in the study were head and neck cancer patients diagnosed as T1-4, N0-3 according to AJCC TNM Staging, 8th edition, and treated in the supine position.

Moreover, the patients were randomized and divided into 3 groups: group A (Code A) using a new mask, group B (Code B) using first reused mask, group C (Code C) using a twice reused mask. The randomization and mask allocation was performed by the Radiotherapy Technician (RTTs) in CT-Simulator.

The pre-treatment verification was performed on three directions: lateral (X-axis), vertical (Z-axis), and longitudinal (Y-axis) and the shift in each directions were recorded. The random error (σ) was defined as the average of a standard deviation of the shift per patient along with particular directions which can easily quantify systematic error (Σ) along with those directions.

The systematic component of the displacement represents the patient movement at the time during the entire course of treatment.[6] The analysis of PTV margin was conducted using random and systematic error data, according to the formula founded by Stroom et al. (2002).[7]

Patient verification was performed using CBCT in the Trilogy Linac machine before the first treatment and every five fractions of the IMRT and VMAT delivery. ICRU 62 reported that the PTV segment is divided into two distinct sub margins, the setup margin which accounts for uncertainties associated with patient setup, and the internal margin which accounts for target motion. [8]

RESULTS AND DISCUSSION

In total, there were 42 patient verification data acquired. The average (mean) displacement and Standard Deviation (SD) in each orthogonal direction (X,Y,Z) are mostly within 0-5 mm, with 1 patient vertical displacement reached 7 mm (due to patient's condition during verification). The complete data are available in Table 1,2, 3.

Table 1.Average Displacement and Standard Deviation (SD) from Mask Type "A" (New Thermoplastic Mask)

No	Average Displacement (mm)			Standard Deviation (mm)		
	Lateral (X)	Longitudinal (Y)	Vertical (Z)	Lateral (X)	Longitudinal (Y)	Vertical (Z)
1	1,0	0,7	1,0	1,0	1,5	5,2
2	0,0	0,0	-2,6	3,4	1,4	2,1
3	0,3	-0,8	-0,5	2,9	1,5	1,3
4	-0,3	-0,5	-2,3	1,0	1,7	4,3
5	0,3	0,0	0,0	0,6	0,0	0,0
6	-1,3	-1,1	1,0	4,9	4,7	2,4
7	-1,2	0,5	0,8	1,9	0,8	1,3
8	-0,3	-0,8	-1,3	0,5	1,5	5,6
9	1,5	2,0	-0,3	1,9	2,9	1,0
10	-0,2	0,4	-1,8	5,0	1,1	0,8

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RESULTS AND DISCUSSION

Table 2. Average Displacement and Standard Deviation (SD) from Mask Type "B" (Once Reused Mask)

No	Average Displacement (mm)			Standard Deviation (mm)		
	Lateral (X)	Longitudinal (Y)	Vertical (Z)	Lateral (X)	Longitudinal (Y)	Vertical (Z)
1	1,0	0,0	-0,3	1,7	4,0	2,5
2	0,0	-1,7	0,0	0,0	5,7	2,0
3	2,0	0,0	0,7	3,5	0,0	1,5
4	-0,3	-0,3	0,0	2,6	1,3	1,4
5	0,1	-0,9	-2,9	1,7	4,4	7,4
6	0,0	-0,3	0,8	0,8	1,0	1,5
7	0,3	-0,7	0,0	0,6	1,2	0,0
8	0,7	2,0	0,7	2,4	3,0	3,3
9	0,0	-0,8	-4,4	1,9	1,1	2,7
10	-3,7	-1,0	-0,3	4,7	0,0	1,5
11	0,2	-0,5	0,2	2,1	5,0	1,9
12	0,0	0,3	-0,3	0,8	0,5	1,3
13	1,3	2,0	1,5	2,1	4,5	3,9
14	-0,6	1,0	0,4	1,1	2,1	1,8
15	2,0	0,0	-0,4	1,7	1,9	0,9
16	-0,7	-0,7	0,3	1,5	2,1	0,6

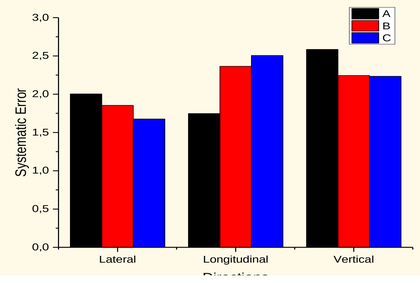
Table 3. Average Displacement and Standard Deviation (SD) from Mask Type "C" (Twice Reused Mask)

No	Average Displacement (mm)			Standard Deviation (mm)		
	Lateral (X)	Longitudinal (Y)	Vertical (Z)	Lateral (X)	Longitudinal (Y)	Vertical (Z)
1	1,3	1,3	1,3	1,5	2,3	1,5
2	-0,4	-1,2	-1,2	1,7	1,8	1,3
3	-1,3	2,3	-0,7	2,1	4,0	1,2
4	-0,7	-1,5	-0,3	0,8	2,7	1,5
5	0,6	-0,7	-1,0	2,0	3,1	3,1
6	0,6	0,6	0,6	0,5	2,2	4,0
7	0,3	-1,6	1,7	3,1	3,3	2,1
8	1,7	-0,7	0,0	2,1	1,8	2,5
9	0,4	-0,1	-1,1	0,8	0,4	2,7
10	-1,0	-5,7	0,3	1,0	5,9	1,5
11	-1,0	-2,3	-1,3	2,6	2,5	4,6
12	1,0	-0,3	-0,3	1,0	0,6	0,6
13	6,0	5,0	0,7	5,3	7,0	2,5
14	0,0	0,7	-0,7	1,7	1,2	2,7
15	0,5	1,0	-0,7	0,5	1,3	1,8
16	-2,2	-0,5	-3,3	2,2	1,8	4,4

Systematic error was acquired by calculating means of standard deviation from all masks types displacements in each orthogonal directions (Table 4, Graphic 1). The systematic errors are similar in each directions for each types of mask. The average numbers are slightly larger in vertical (Z) direction. Random error is acquired from square root of systematic error in each orthogonal directions fom each mask types (Table 5, Graphic 2). Based on the data observed, average systematic and random errors are the highest in vertical direction. The PTV Margin were then counted using formula founded by Stroom et al (2002).[7] in Table 6 and Graphic 3.

Table 4. Systematic Error

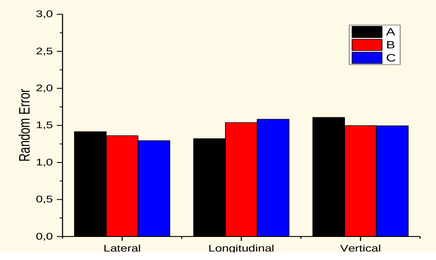
Direction	Mask Type	Systematic Error (mm)
Lateral (X)	A	2,0
	B	1,9
	C	1,7
Longitudinal (Y)	A	1,7
	B	2,4
	C	2,5
Vertical (Z)	A	2,6
	B	2,2
	C	2,2



Graphic 1. Systematic Error

Table 5. Random Error

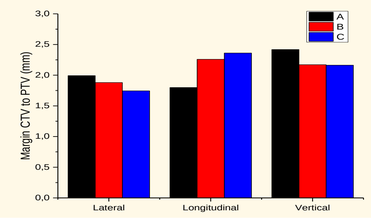
Direction	Mask Type	Random Error (mm)
Lateral (X)	A	1,4
	B	1,4
	C	1,3
Longitudinal (Y)	A	1,3
	B	1,5
	C	1,6
Vertical (Z)	A	1,6
	B	1,5
	C	1,5



Graphic 2. Random Error

Table 6. CTV-to PTV Margin

Directions	Mask Type	CTV-to-PTV Margin (mm)
Lateral (X)	A	2,0
	B	1,9
	C	1,7
Longitudinal (Y)	A	1,8
	B	2,3
	C	2,4
Vertical (Z)	A	2,4
	B	2,2
	C	2,2



Graphic 3. CTV-to PTV Margin

CONCLUSION

We studied the magnitude of daily patient positioning errors corrected by Cone Beam CT image registration. The composite geometric error of three directions showed that the CTV to PTV margin is less than 3 mm and the comparison between each mask (new, first reused, and twice reused masks) showed no mark difference. This research could be used to justify the use of new and reuse thermoplastic masks in head and neck cancer cases treated with IMRT/VMAT technique in the developing country. To improve treatment efficacy, we encourage other radiotherapy centers to calculate the magnitude of the CTV to PTV margin in the new and reuse the thermoplastic mask.

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