DOSES FOR ORGANS AT RISK FOR PATIENT UNDERGOING MAMMOSITE OR INTERSTITIAL LEFT BREAST BRACHYTHERAPY 1500

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ABSTRACT

The increasing number of breast cancer cases over the world motivates researchers to do their effort in development of a safe radiation therapy that has the ability to target the tumor itself and spare adjacent organs. The recommendations of science communities give a wide choice for physicians and patients to choose a suitable and safe brachytherapy technique to cure breast cancer cases. The eyes of scientists are looking for a technique by which tumor cells can be destroyed, as fast and effective as it must be safe for patients and workers. Many different researchers gave different opinions for using one way of radiation therapy in curing breast cancer on tumor cells or used treatment plan readings to compare doses to internal organs and tissues. The need for a comprehensive view on doses delivered by one of the breast brachytherapy techniques (MammoSite single lumen balloon brachytherapy system (MBS) and multicatheter interstitial brachytherapy (MIB)) to adjacent organs and tissues is the way to avoid the recurrence of cancer or destroy some organs. The safe technique is the most appropriate way for healthy tissues and organs by which receive lowest amount of radiation. The dosimetric comparison between mentioned methods inside human phantom is by the use of high sensitive dosimeter TLD 100H at positions of organs at risk (OARs) then data can be collected and comparisons will be made.

Key Words: MammoSite, Interstitial, Brachytherapy, Treatment Plan, TLD 100H, OARs.

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Introduction

Risk of radiation to organs and tissues is an expression of fatal cancer per centigray (cGy) which differs due to the difference in mortality rates for cancer types. The overall cancer death cases risk due to radiation has low values with comparison to baseline lifetime cancer death cases, this risk increases by 0.25 percent for each centigray of radiation dose to the body as whole (Mossman, 1996). There is no probability to cure cancer of any patient without inducing normal tissue morbidity or even maximizing the cure and minimizing the probability of injury (Levitt, Purdy, Perez, & Poortmans, 2012). Female breast, thyroid, and leukemia cancers have the highest sensitivity to radiation induction, but moderate sensitivity to radiation are cancers of lungs, lymphomas, colon, stomach, liver and biliary tract, pancreas, and pharynx.

The feature of induced cancer takes a long period of time, may be decades, between exposure and the recurrence of cancer cells. Ionizing radiation has the effect as human carcinogen at high doses, no evidence at low doses, but it is popular within the scientific community that radiation risk is proportional directly to dose at any value of dose even low doses because cell killing plays an important role by promoting cell division in healthy cells and most side effects of radiation therapy occur due to the high dose delivered to patient and vary with person's health, the type and location of tumor, and treatment dose (Mossman, 1996).

The first organs will react to radiation are blood forming organs in the bone marrow by which the number of white and red cells in blood will decrease if the dose is in order of 1 to 2 Gy, then the failure of immune system leads to life threatening infection within two weeks after irradiation, but bone marrow has a chance to recover if the dose is below 5 Gy and it will begin the production of blood cells again. The median lethal dose (LD50) for humans is in the range of 3 to 10 Gy that causes the damage of epithetical cells of intestine and stomach in the range of 10 to 100 Gy, or by the damage of the central nervous system if exposed to above than 100 Gy. Small doses have no immediate observable acute effects, but late effects consisting of cancer and genetic effects can be observed (Thormod & Maillie, 2003). The radiation can induce myocardial damaged by changing in the endothelial cells, increasing endothelial cell proliferation, and endothelial activation which leads to decrease the density of capillary, loss the capillary, and late myocardial degeneration in areas the enzyme alkaline phosphatase present. Heart failure

develops in 100% of whole heart irradiated animals for a single dose greater than 15 Gy and capillary density was reduced for the use of a 10 Gy dose or less, so the damage progressed slowly. A number of molecules were involved in the radiation effect on the capillary and endothelial cells. Experiments on rats proved the presence of atherosclerotic changes after exposure which induces the plaques to present an unstable inflammatory phenotype to be more ruptured and give rise to thrombotic complications. The irradiation of large vessels leads to area of focal damage to form atherosclerotic lesions. There is little evidence of the damage of mature cardiac myocytes due to radiation therapy, it stopped replication but the damage will be from indirect mechanism but there is no doubt of the damage of pericardium by radiation which also induces the valvular disease and damage the conduction system through microvascular or macrovascular damage due to the sensitivity of radiation that has different values between blood vessels themselves due to the thickness of its wall (Ewer & Yeh, 2013). Lung is one of organs with moderate sensitivity to radiation; its injury by radiation is directly proportional to dose and volume effects but lung cancer incident risk due to ionizing radiation which has a high mortality rate about 90% and its risk per centigray is about 8×10^{-6}. Radiation pneumonitis is the acute development of lung injury by irradiation, and lung fibrosis is a late effect of its injury. Among populations, underground miners had observed as lung excess cancer, but lung cancer can be induced by radiation (Mossman, 1996). The first discovered damage of lung by irradiation was in 1920s, by which two main phases of irradiation injury were documented; radiation fibrosis and pneumonitis but separated by time. Pneumonitis occurs after six months after treatment of lung but fibrosis after one year (Small & Woloschak, 2006). Rib's fracture can be induced by radiation after external radiotherapy to the chest which recognized as a late complication and several factors affect rib fracture like dose, volume, and patient's characteristics. Rib fracture site was induced by median dose of 46 Gy (Kanemoto, et al., 2013). From 116 lung cancer patients, there were 28 patients experienced radiation-induced rib fracture (Asai, et al., 2012). A late toxicity for skin was noted if the distance is less than 0.6 cm between skin and MammoSite balloon catheter (Cuttino, Heffernan, Vera, Rosa, Ramakrishnan, & Arthur, 2011). Up to 14% of patients used MammoSite brachytherapy had chronic pain may had a relation with chest wall toxicity, which increased when the dose to chest wall exceeds the prescribed dose by125% . Multicatheter technique delivers lower mean doses to skin and chest wall (Cuttino, Todor, Rosu, & Arthur, 2009). The entire ipsilateral of the chest wall is considered to be at risk for recurrence in

mastectomy cases (Haydaroglu & Ozyigit, 2012). Skin toxicity is a part of skin dose (Vargo, et al., 2014).

Materials and Methods

RANDO® woman heterogeneous phantom has lungs, spinal cord, sternum, ribs, and breast between slice 9 and 23 with densities and compositions like human, and each slice has a thickness of 2.5 cm.

The treatment plans were done for RANDO® phantom with homemade breast by mixing equal quantities of beeswax and paraffin wax. The mixture form medium size breast with density of 0.93 $g.cm^{-3}$. CT scan data (Philips Brilliance Big Bore CT scan) were made for the whole phantom, first with 9 catheters as multicatheter interstitial left breast brachytherapy (MIB) inside left breast; the catheters were arranged in two lines with horizontal distance of 1 cm and vertical distance of 1.5 cm around the lumpectomy cavity. The second CT scan was for the same phantom, for MammoSite balloon brachytherapy system (MBS). The balloon was inserted in the supposed lumpectomy cavity and inflated with saline (NaCl 0.9%) for a diameter of 5 cm. Data from CT scan were transferred to treatment planning area to develop treatment plans by the use of Nucletron Oncentra Master Plan (TPS). Treatment plans took into account ABS, TG-43, and RTOG recommendations. Treatment plans were made for one fraction (340 cGy) by the use of HDR Ir-192 as a radioactive source. The first point in treatment planning is the definition of organs of interest and PTV, then catheter reconstruction, activation the source (Ir-192) and its activity with the number of fraction should be delivered to patient.

Figure 1: CT scan for a) multicatheter interstitial phantom, b) MammoSite balloon phantom.

The dosimetric goals can be achieved after calculating the followings:

- Dose nonuniformity ratio

(DNR) $DNR = \frac{V150}{V100}$ (1),

where V100 and V150 are the absolute volumes in cm^3 irradiated by 100 and 150% of the prescribed dose (PD).

- Dose homogeneity index (DHI)

$DHI = \frac{V150-V100}{V100}$ (2),

- Coverage index (CI) gives the amount of the fraction of the planned target volume (PTV) receives the prescribed dose

$CI = \frac{V100}{100}$ (3),

The use of TLD 100H in a wide dosimetry program has a special interest because of its extreme sensitivity to maximum readout temperature and the consideration of implementation in routine dosimetry (Moscovitch, et al., 2006). The TL material has a tissue equivalent property and the (LiF:Mg,Cu,P) material has a high sensitivity and near flat photon energy response without the need to use correction factor (Lou & Rotunda, 2006). TLD 100H is an advanced TLD due to its new dosimetric material and has insignificant fade along simple glow curve structure up to one year, so it is a premier choice for dosimetry (Ramlo, Moscovitch, & Rotunda, 2007).

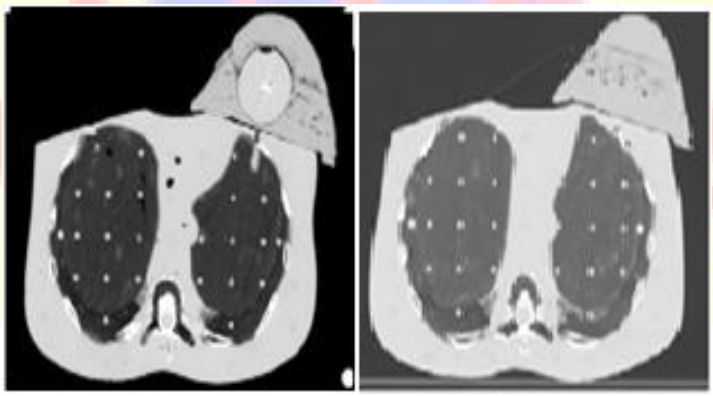

Figure: 2 Location of a) balloon single lumen catheter, b) interstitial catheters, inside breast phantoms.

The CT imaging system is used with slice thickness of 3 mm in every case to reconstruct the catheters and contour the planned target volume (PTV).

Results:

Table 1: Doses delivered to organs at risk measured by TP.

Organ (TP)	D_{MIB}		D_{MBS}	
	cGy	%PD	cGy	%PD
Heart	102	30	136	40
Left lung	136	40	256	75.29
Right lung	14	4.11	30	8.82
Left ribs	102	30	311.8	91.7
Spinal cord	6	1.765	11	3.23
Sternum	20	5.88	46	13.53
Left breast skin	333.2	98	340	100
Chest wall	238	70	340	100
Right breast skin	15.3	4.5	27.2	8

Table 2: Doses delivered to organs at risk measured by TLDs.

Organ (TLD)	D_{MIB}		D_{MBS}	
	cGy	%PD	cGy	%PD
Heart	57.12	16.8	68.73	20.2
Left lung	68.03	20	78.04	22.9
Right lung	11.36	3.3	16.4	4.8
Left ribs	68.03	20	78.04	22.2
Spinal cord	8.43	2.5	11.23	3.3
Sternum	21.08	6.2	21.37	6.3
Right ribs	14.16	4.2	14.04	4.1
Right breast skin	11.36	3.3	16.4	4.8

Table 3: Doses delivered for PTV

PTV	MIB	MBS

V50	2.3	5.9
V100	97.7	94.1
V150	69.1	44.1
V200	35.53	13.9
V250	21.8	4.1
DNR	0.71	0.47
DHI	0.29	0.53
CI	0.977	0.941

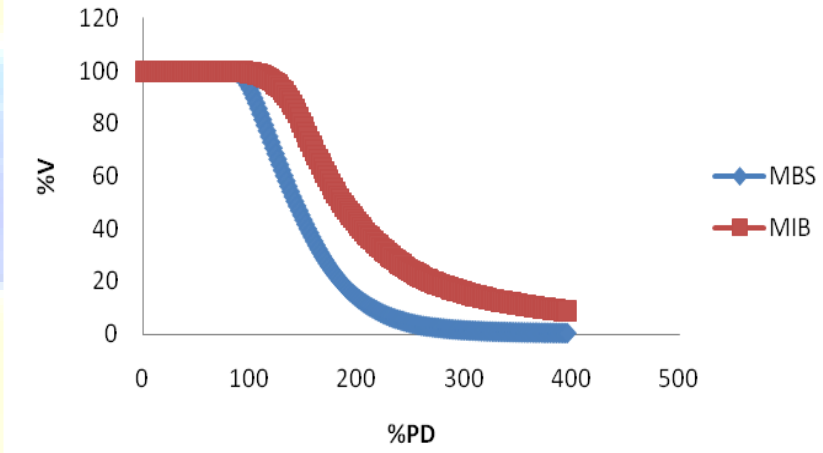

Figure 1: The dose-volume histogram for PTV

Conclusion:

Both of treatment plans and dosimetry by TLD-100H tell about high doses delivered by MBS to organs at risk and high dose to PTV by MIB that makes MIB a noble brachytherapy technique for left breast brachytherapy, but both of them have a dose distribution less than dose limits for OARs with good achievement of ABS, TG-43, and RTOG protocol recommendations.

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