DOSES FOR ORGANS AT RISK FOR PATIENT UNDERGOING MAMMOSITE BRACHYTHERAPY SYSTEM OF LEFT BREAST WITH HDR IR-192

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Abstract

Limited dosimetric data using human phantom were used to predict dosimetric information about the hazard of radiation delivered to adjacent organs to the left breast during the use of MammoSite single lumen applicator. This study uses Rando® female phantom, TLD 100H, and treatment planning to measure doses delivered to PTV, Breast, and OARs. The use of MammoSite single balloon catheter (5 cm diameter), homemade breast phantom, a number of dosimeters (TLD 100H), annealing device, Harshaw TLD reader, Rando® female phantom, CT scan, Oncentra Master Plan version 4.3, and microSelectron v3 treatment unit (mSel v3 (18)). After positioning of the MBS balloon inside the lumpectomy cavity which has a diameter of 5 cm and taking a CT scan; the treatment planning was developed to a achieve ABS, TG-43 protocol and RTOG-0413 protocol recommendations and optimizing dwell positions and dwell times. The delivery of radiation was by the use of 340 cGy per fraction after treatment planning was exported to the treatment unit device and dosimeters (TLD 100H) were positioned at certain locations inside phantom then doses were read.

Keywords: MammoSite, Organs at risk, brachytherapy.

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Introduction

The decision of choosing radiation therapy after breast surgery (mastectomy or lumpectomy) is to enhance survival rate of patients and to reduce cancer recurrence of OARs (Haydaroglu & Ozyigit, 2012). After breast conserving surgery (BCS), patient with early stages (I or II) must undergo a radiation therapy to kill residual cancer cells around lumpectomy cavity. Different types of radiation therapy offered in hospitals, like external beam radiation therapy and internal radiation therapy. Brachytherapy is an accelerated partial irradiation which uses a radioactive source to inter a certain locations (dwell positions) inside the body to deliver a certain amount of dose to the tumor itself or areas around it (Tice, 2008). The external radiation therapy maybe a difficult choice for elderly women, working women, and who lives far away from hospitals; it needs more than 5 weeks, but brachytherapy delivers the treatment within 5 days so 71,000 women in the USA treated with brachytherapy every year (ABS, 2014). The need for brachytherapy is to deliver radiation dose to 1-2 cm tissues around the lumpectomy cavity (Jacob & Finlayson, 2010).

Balloon brachytherapy considered necessary for some patients at early stages (I or II) of breast cancer because it irradiates a limited needed portion of breast, so fewer fractions with large dose per fraction were be needed to reduce treatment time to 5 days (BLUE, 2014). Some frequent steps should be passed before the delivery of radiation; patient history, simulation, imaging and target definitions, treatment planning and radiation delivery followed by evaluating clinical outcomes (Heimann & Hard, 2010).

Balloon based brachytherapy delivers the highest dose to tumor itself than external radiation therapy methods like IMRT or 3D conformal radiotherapy (3D-CRT) (Khan, et al., 2006). MammoSite balloon brachytherapy system is simple for both physician and patient, by which the balloon surface conforms to the target. The tumor size, breast characteristics, and the location and geometry of the lumpectomy cavity must be taken into consideration before starting treatment procedure. Within MammoSite brachytherapy; the balloon volume after inflation, the symmetry of balloon, the conformance of cavity to the applicator, and the balloon-skin distant must be considered (Wazer, Arthur, & Vicini, 2009).

MammoSite balloon radiation therapy system (RTS) is a new HDR ^{192}Ir brachytherapy method. The balloon must be in contact with lumpectomy cavity surfaces with minimum 7 mm balloon surface to skin distance (Wojcicka, Lasher, Malcom, & Fortier, 2007), it is a fast and effective treatment method in early stages of breast cancer (Mille, Xu, & Rivard, 2010), and a sole modality for delivering radiation to the tumor in achieving local control due to the minimal toxicities and cosmetic outcomes (Benitez, et al., 2007), the dose reductions for the smallest balloon is 9% compared to 12% for the largest balloon (Kassas, Mourtada, Horton, Lane, Buchholz, & Strom, 2006). The balloon catheter is inserted inside the breast into the lumpectomy cavity and inflated with saline to stay there a long the treatment period not more than 5 days, by which a radioactive source by afterloader machine (HDR unit) enters its centre to irradiate surrounding tissues around the balloon (Ranatunga, 2014). The five year outcomes of MammoSite balloon brachytherapy were breast cosmetic outcome, low late toxicity and excellent control of residual cancer cells (Vargo, et al., 2014), its insertion into lumpectomy cavity is easier than interstitial catheters and has one entry side but local infection may be increased due to the balloon placement (Tice, 2008), but the MammoSite balloon catheter must be removed, if the dosimetry of PTV, skin, or ribs is unacceptable (Gurdalli, Kuske, Quiet, & Ozer, 2011). The acceptable MammoSite balloon brachytherapy is that which obeys ABS, TG-43 protocol, and RTOG-0413 protocol recommendations.

The use of CT (computed tomography) in simulation and planning of radiotherapy determines the exact location of tumor and lumpectomy cavity, and helps in planning a homogenous radiation dose distribution with sparing critical structure like heart, lung and skin (Koylu, Olacak, & Haydaroglu, 2013). Thermoluminescence dosimeter (TLD 100H) 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), its material has a high sensitivity and near flat photon energy response without the need of using a correction factor (Lou & Rotunda, 2006). To measure equivalent doses to organs and tissues in the human body, the human phantom is a major achievement (Krstic & Nikezic, 2011), which represents the human body for important purposes like dosimetry and treatment planning for radiotherapy (Gialousis, et al., 2006).

Materials and Methods

Thermoluminescence dosimeters (TLD 100H) were used inside Rando® female phantom to measure doses to organs inside the phantom by the use of Harshaw® 3500 TLD reader. The soft tissues of Rando® female phantom were made of urethane formulation which is close in mass density and effective atomic number to muscle tissue with the distribution of fat within; its lung density which fills the rib cage is the same as the density of human lung tissue in median respiratory state, also its skeleton is the same as human skeleton. The RANDO® woman phantom represents adult woman with 163 cm tall and 54 kg mass. The phantom is sliced at 2.5 cm intervals and has holes in grid patterns to enable the insertion of TLDs (RANDO, 2014).The MammoSite system has a single lumen catheter and its balloon diameter is 5-6 cm, it was inserted into the breast phantom which was made at the lab by mixing same quantities of paraffin wax and beeswax to shape a medium breast size as mentioned by Saleh (2010) with average density of 0.93 gm/cm^3. The final phantom consists of Rando® female phantom with breast which includes the MammoSite RTS. The treatment planning began by taking a CT scan for the phantom at the department of radiotherapy (HUSM) by the use of Philips Brilliance Big Bore CT scan. The output images were transferred to treatment planning section to develop a suitable treatment planning for the case by the use of Nucletron Oncentra master plan program that started the definition of CTV, the target volume, and regions of interest. The balloon is filled with saline (water solution with 0.9% NaCl with density of 1.0046 g/cm^3) and has a diameter of 5 cm which considered as the CTV. The dwell positions (18 dwell positions) and dwell times (7.448 minute) along the single lumen catheter (120.1 mm) were determined to achieve the homogeneity of dose distribution and ABS, TG-43 protocol, and RTOG-0413 protocol recommendations. The radiation delivery to the phantom was after the treatment planning data transferred from the Nucletron Oncentra (TPS) to the treatment control station (TCS) of HDR Brachytherapy machine (the afterloader). The TLDs sensitivity and calibration were examined before localization it inside the phantom and before irradiation. The annealing protocol followed was heating TLD 100H to 240˚C for 10 minutes before irradiation and preheat it to 100˚C for 10 minutes before reading its signals. The afterloader device delivered 340 cGy of dose per fraction by the use of radioactive source (Ir^{192}), then TLDs were removed and TLD reader (Harshaw 3500®) was used to read signals from irradiated TLDs. The procedure repeated for 3 times and the average of TLDs output signals were taken.

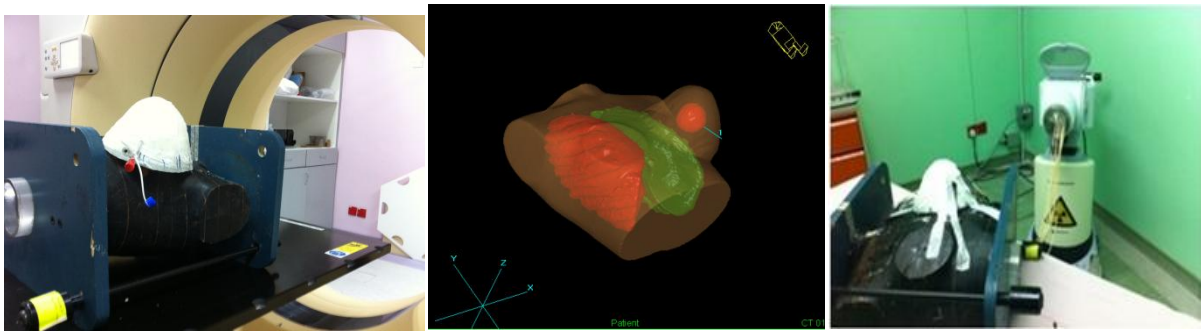

Fig. 1: MammoSite brachytherapy system treatment procecures.

The vertical distance between the centre of balloon and the edge of left lung was 37 mm. differential dose volume histogram (DVH) describes the volume of organ receives exactly the given dose but the cumulative dose volume histogram describes the volume receives greater than or to that dose. The dose delivered to PTV has an important issue, so the dose homogeneity index (DHI), dose nonuniformity ratio, and coverage index should be calculated by the use of following equations:

$$DHI = \frac{1 - V100}{V100}$$

$$DNR = \frac{V150}{V100}$$

$$CI = \frac{V100}{V_{100}}$$

Where: V150 and V100 are the volumes of PTV received 150%PD and 100%PD respectively, and V_{100} is the volume of 100% of PTV.

Results

Treatment planning showed the acceptable data and factors for MBS as shown in the following table:

Table 1: Recommendation of brachytherapy protocols and the MammoSite results.

Recommendations	ABS	TG-43	RTOG-0413	MBS
V90	≥ 90% PTV			108%
V150 for normal breast tissue (cm^3)	< 50 cm^3			19.42
V200 for normal breast tissue (cm^3)		< 10 cm^3		5.53
Maximum breast skin dose (%PD)	< 145%			100%
DHI	≥ 0.75			0.736
Dose (per each fraction)	340 cGy			340 cGy
DNR		≤ 0.35		0.264
CI		≥ 0.90		0.941
balloon volume (MSB)			≤ 30%	14%
balloon symmetry			≤ 2 mm	2 mm
balloon-surface distance			≥ 7 mm	16 mm
60% of whole breast volume receives			≥ 50% PD	68.9
V50			< 60% $V_{total\ organ}$	* 2.2% phantom * 17% left lung *0% right lung

The treatment plan (TP) dose delivery and measured doses by irradiated TLDs gave the following maximum doses for organs at risk as measured at TLDs location and its isodose curves. The TP measures the dose at the edge of the organ but TLD has its own defined location inside the organ.

Table 2: Maximum doses for OARs due to treatment plan (TP) and dosimeters (TLDs).

Organ	D_{max} (TP)		D_{max} (TLD)	
	cGy	%PD	cGy	%PD
Heart	105	30.9	70.1	20.6
Left lung	80	23.5	29.9	8.8
Right lung	23	6.8	16.5	4.9
Left ribs	80	23.5	29	8.5
Spinal cord	15	4.4	11.43	3.4
Sternum	38	11.2	21.7	6.4
Right ribs	11	3.2	10.91	3.2
Right breast (skin and tissues)	23	6.8	16.5	4.9

Conclusion

The MammoSite device can offer cosmetic outcomes and ease insertion inside the breast with comparison to multicatheter interstitial brachytherapy. The multiple dwell position method improved dose coverage with a slight decrease in dose homogeneity. MammoSite brachytherapy system spares OARs and obeys the recommendations of brachytherapy protocols. Dosimeters take into account the effect of heterogeneity of tissues and organs.

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