Radiation Physics and Chemistry 132 (2017) 41–45

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

Comparison of treatment planning techniques in treatment of carcinoma of left breast: Second cancer perspective

Vasanthan Sakthivel[a,b,*], Ganesh Kadirampatti Mani[a,c], Sunil Mani[b], Raghavendiran Boopathy[b]

[a] Research and Development Centre, Bharathiar University, Coimbatore, India
[b] Advanced Medical Physics, Houston, TX, USA
[c] Department of Radiation Physics, Kidwai Memorial Institute of Oncology, Bangalore, India

ARTICLE INFO

Keywords:
Breast cancer
Second cancer
Electronic compensator
Secondary cancer risk
Treatment planning

ABSTRACT

Aim: To compare the secondary cancer risk (SCR) between different planning techniques for treatment of Ca. Left-Breast patient.

Materials and methods: Five treatment plans; 3DCRT tangential fields with physical wedge (PW), enhanced dynamic wedges (EDW), electronic compensator (EC), IMRT tangential fields (ITF) and Volumetric modulated arc (VMAT) plan (partial arcs) with 6 MV photon beams were generated for a carcinoma of Left breast patient of age 40 to a prescription dose of 50Gy in 25 fractions. The SCR was estimated using the organ equivalent dose (OED) concept with a linear-exponential, a plateau, and a linear dose-response model for OARs. Also, the low dose-bath volume (5Gy) was calculated for all the plans.

Results: For contra lateral breast the SCR relative to PW were (linear, plateau, linear-exponential) (−26.0%, −35.0%, −39.0%) for VMAT, (−50.0%,−50.0%,−51.0%) for ITF, (−48.0%, −49.0%,−49.0%) for EC and (−33.0%, −24% , −25.0%) for EDW respectively. The relative SCR (plateau) for heart and left lung were (−66.0% & −73.0%) for VMAT, (−20.0% & −6.0%) for ITF, (−24.0% & −18.0%) for EC and (−17.0% & −14.0%)for EDW. In contrast, for skin the relative SCR (linear - exponential) were 78.0%, −8.0%, −13.0% and −10.0% for VMAT, ITF, EC and EDW respectively. The 5Gy low dose volume relative to PW for VMAT was 201.45%, whereas the same for ITF, EC and EDW were 17.0%, −7.33% and −4.3%.

Conclusion: Compared to all plans, VMAT plan showed high conformity for CTV and superior heart and left lung sparing. But SCR for skin and the low dose bath volume were significantly high in VMAT. ITF plan showed relatively better sparing for contra lateral breast and heart. EC plan shows moderately good sparing for OARs while scoring least SCR value for skin next to EDW. EDW and PW plans were similar but later had high SCR for contra lateral-breast. Planning techniques like ITF and VMAT can be strongly considered for left breast, provided better skin sparing techniques and less dose spillage can be achieved.

1. Background

Radiotherapy prevents local recurrence of breast cancer after breast conserving surgery (Lumpectomy). The variation in local treatment affects the risk of locoregional recurrence and could affect the long term breast cancer mortality. Early breast cancer patients have a good survival rate and they constitute a very large radiotherapy treatment population (Fisher et al., 1989; Lingos et al., 1991).

Conventional breast cancer radiotherapy mainly employs medial and lateral tangential fields (Kutcher et al., 1996; Solin et al., 1991). But, conventional breast irradiation irradiates parts of lung, heart and in cases, the contra lateral breast. This led to the implementation of various other novel RT techniques such as IMRT and VMAT for treatment of left breast to achieve high target homogeneity and superior critical organ sparing (Kestin et al., 2000; Chang et al., 1999; Nicolini et al., 2011; Barnett et al., 2012). On contrary, employing IMRT and VMAT increases total body exposure and high low dose bath volume due to scattered and leakage radiation sparking the possible risk of second cancer. So, estimation of secondary cancer after RT are becoming vital for quality planning and its analysis (Donovan

Abbreviations: CR, Second Cancer Risk; VMAT, Volumetric Modulated Arc Therapy; OED, Organ Equivalent Dose; 3DCRT, Three Dimensional Conformal Radiation Therapy; PW, Physical Wedge; EDW, Enhanced Dynamic Wedge; ITF, IMRT tangential fields; OAR, Organ at Risk; CTV, Clinical Target Volume; GTV, Gross Tumor Volume; DVH, Dose Volume Histogram; MLC, Multi Leaf Collimator; CW & CCW, Clock wise & Counter clock wise

* Corresponding author at: Research and Development Centre, Bharathiar University, Coimbatore, India.
E-mail addresses: vasanthan.sakthivel@gmail.com (V. Sakthivel), kmganesh1@gmail.com (G. Kadirampatti Mani), ssj8615@wans.net (S. Mani), raghav213@gmail.com (R. Boopathy).

http://dx.doi.org/10.1016/j.radphyschem.2016.11.009
Received 29 August 2016; Accepted 18 November 2016
Available online 20 November 2016
0969-806X/

et al., 2012; Schneider et al., 2005; Brenner et al., 2007).

The main objective of this study was to estimate, analyze and compare SCR for different planning techniques (EDW, EC, ITF and VMAT) in the treatment of left breast . In this study, we report SCR using the concept of organ equivalent dose proposed by U Schneider et al (Schneider et al., 2005). Since, the mean organ dose is not a linear function of dose (because dose inhomogenity within organ), the concept of organ equivalent dose was introduced. OED is a dose response weighted dose averaged over the whole organ volume. The risk ratios for various treatment plans are equivalent to OED ratios which can be determined based on organ specific dose response relationship and the dose volume histogram.

2. Aim

To compare the secondary cancer risk (SCR) between different planning techniques for treatment of Ca. Left-Breast patient.

3. Methods and materials

3.1. Patient data and contouring

Forty year old patient was selected for study. The patient was scanned for treatment planning. CT scans were performed at 2.5 mm slice spacing and the volumes are delineated based on RTOG guidelines (RTOG study 1005). The breast CTV included the apparent CT glandular breast tissue, lumpectomy CTV and it incorporated the consensus definitions of anatomical borders. The lumpectomy GTV included seroma and surgical clips. To account for organ motion during treatment a margin of 8.0 mm was assigned to breast CTV to form PTV. Then the PTV was trimmed 3 mm to the right to minimize lung, heart and contra lateral breast involvement. The volume of PTV was 1,473cc. The prescription dose to breast PTV was 50Gy in 25 fractions, only initial plan is included in this study boost plans are not considered. Contra lateral breast, left lung, heart, skin and spinal cord are contoured for OED analysis.

3.2. Treatment planning

An Eclipse treatment planning system (Varian Medical Systems, Palo Alto, USA) was used to generate five treatment plans on the acquired computed tomography (CT) scan. Anisotropic analytical algorithm was used for dose calculation and tissue heterogeneity correction was used for all treatment plans (Aref et al., 2000; Chin et al., 1989; Chu et al., 1985).

3.3. Plan1: Physical Wedge based planning

For treatment planning, the tangential fields are oriented based on the contoured breast CTV. Fine tuning of tangent angle was performed to minimize lung involvement in treatment field. Tangent angle used are 310° (Medial) and 130° lateral. At central axis 1.5 cm depth of lung was included to efficiently cover the CTV. A radiation flash of 2 cm was given from each field. Tissue compensation for tangents were achieved using wedge filter in lateral field (6 MV) and the same is achieved in medial field (6 MV) via field in field technique. MLC's were used to shape the treatment field (Kutcher et al., 1996; Neal et al., 1994; Aref et al., 1998).

3.4. Plan2: Enhanced Dynamic Wedge based planning

Same beam orientation and field shaping used in plan1 was used for Plan2, but tissue compensation and dose homogeneity was achieved using EDW (Movement of Y-jaw during irradiation at variable speed to achieve wedged dose distribution). EDW 30° was used both in medial and lateral tangential fields.

3.5. Plan3: electronic compensator based planning

Electronic compensation involves beam modulation using multi leaf collimators. Eclipse offers two form of electronic compensation - Planar and irregular surface compensator (ISC). For this study ISC was used to compensate for breast tissue irregularity using the preset tangents, as adopted by Hansen et al (Valdagni et al., 1992; Hansen et al., 1997).

3.6. Plan4: IMRT planning

The IMRT technique (sliding window) employs two tangent fields (310° and 130°) and two more fields which were ten degree off tangents (300° and 140°). The two additional fields along with tangents helped in desired optimization and sparing of heart and left lung. The IMRT plan was optimized to cover breast PTV to clinically acceptable level (95% of the prescribed dose covers 95% volume of PTV) and to spare heart, left lung to acceptable tolerance limits (V30 less than 3% for heart and V20 less than 20% for lung) (ICRU report 83, 2010). To accommodate intra fraction motion, intensity modulated fields are edited using skin flash tool to provide additional flash (Singla et al., 2006).

3.7. Plan5: VMAT planning

VMAT (VMAT) plan with four partial arcs was generated in eclipse platform using progressive resolution optimization algorithm (PRO). The gantry angles for first two arcs were 310 - 130 degrees (CW and CCW) and 310 - 179.9 degrees (CW and CCW) for the other two arcs. The PTV was expanded one cm beyond body artificially and assigned soft tissue HU to incorporate skin flash (Nicolini et al., 2011; Johansen et al., 2009; Tsai et al., 2012).

3.8. Plan analysis and comparison

The five treatment plans generated were normalized based on fixed CTV volume and coverage criteria (Wenyong et al., 2011). To attain clinically similar and acceptable plans, all plans are normalized so that, 95% of prescribed dose covers 95% of PTV volume. For each plan the calculated DVH data for heart, left breast, contra lateral breast and skin are exported in differential DVH data format and imported into indigenously programmed OED predictor. The OED predictor derives the value of all dose voxels within each organ from DVH, and weighs it with an appropriate relation selected (linear, plateau or linear threshold) for radiation induced cancer and divides it by the total organ volume to calculate OED (Donovan et al., 2012; Uwe Schneider et al., 2011). Additionally, low dose bath volume (5Gy) was measured in cc and recorded for each plan for further analysis.

3.9. Second cancer risk modeling

Radiobiological modeling of the risk of radiation-induced tumors following high dose radiation is based on a dose–response relationship. The risk will generally rise with radiation dose at low doses, reach a maximum value and then decline with further increase in dose. The magnitude of risk and the dose at which this risk is maximum are strongly dependent on the kinetics of repopulation.. The most reliable way to reduce the risk of second tumors is to reduce radiation dose further at sites where the dose is already low (Sachs et al., 2005).

Various risk models have been developed to predict second cancer incidence. When the doses are less than 2Gy, the dose response relationship is a linear function of risk, therefore cancer incidence is directly proportional to the mean dose of the organ. Whereas, when the dose was greater than 2 Gy and distribution is heterogeneous, the relationship is no longer linear. The relationship curve will vary linear exponentially because of the sterilization of mutated cells (Sachs et al., 2005).