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Original article

Comparison of dose distributions and organs at risk (OAR) doses in conventional tangential technique (CTT) and IMRT plans with different numbers of beam in left-sided breast cancer

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ABSTRACT

Aim: Our aim was to improve dose distribution to the left breast and to determine the dose received by the ipsilateral lung, heart, contralateral lung and contralateral breast during primary left-sided breast irradiation by using intensity modulated radiotherapy (IMRT) techniques compared to conventional tangential techniques (CTT). At the same time, different beams of IMRT plans were compared to each other in respect to CI, HI and organs at risk (OAR) dose.

Background: Conventional early breast cancer treatment consists of lumpectomy followed by whole breast radiation therapy. CTT is a traditional method used for whole breast radiotherapy and includes standard wedged tangents (two opposed wedged tangential photon beams). The IMRT technique has been widely used for many treatment sites, allowing both improved sparing of normal tissues and more conformal dose distributions. IMRT is a new technique for whole breast radiotherapy. IMRT is used to improve conformity and homogeneity and used to reduce OAR doses.

Materials and methods: Thirty patients with left-sided breast carcinoma were treated between 2005 and 2008 using 6, 18 or mixed 6/18 MV photons for primary breast irradiation following breast conserving surgery (BCS). The clinical target volume [CTV] was contoured as a target volume and the contralateral breast, ipsilateral lung, contralateral lung and heart tissues as organs at risk (OAR). IMRT with seven beams (IMRT7), nine beams (IMRT9) and 11 beams (IMRT11) plans were developed and compared with CTT and among each other. The conformity index (CI), homogeneity index (HI), and doses to OAR were compared to each other.

Results: All of IMRT plans significantly improved CI (CTT: 0.76; IMRT7: 0.84; IMRT9: 0.84; IMRT11: 0.85), HI (CTT: 1.16; IMRT7: 1.12; IMRT9: 1.11; IMRT11: 1.11), volume of the ipsilateral lung receiving more than 20 Gy ($>V_{20\,Gy}$) (CTT: 14.6; IMRT7: 9.08; IMRT9: 8.10; IMRT11: 8.60), and volume of the heart receiving more than 30 Gy ($>V_{30\,Gy}$) (CTT: 6.7; IMRT7: 4.04; IMRT9: 2.80; IMRT11: 2.98) compared to CTT. All IMRT plans were found to significantly decrease $>V_{20\,Gy}$ and $>V_{30\,Gy}$ volumes compared to conformal plans. But IMRT plans increased the volume of OAR receiving low dose radiotherapy: volume of contralateral lung receiving 5 and 10 Gy (CTT: 0.0–0.0; IMRT7: 19.0–0.7; IMRT9: 17.2–0.66; IMRT11: 18.7–0.58, respectively)

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and volume of contralateral breast receiving 10 Gy (CTT: 0.03; IMRT7: 0.38; IMRT9: 0.60; IMRT11: 0.68). The differences among IMRT plans with increased number of beams were not statistically significant. IMRT significantly improved conformity and homogeneity index for plans. Heart and lung volumes receiving high doses were decreased, but OAR receiving low doses was increased.

1. Introduction

Breast conserving surgery (BCS) followed by radiotherapy is highly effective for local control of early-stage breast cancer. Whole breast radiotherapy (WBR) after tumor excision generally includes 5 (23–25 fractions) weeks of external beam radiotherapy for the whole breast (46–50 Gy) followed by a boost to the tumor bed with an additional 7–10 fractions of external beam radiotherapy. Several different techniques have been developed in order to achieve optimal dose delivery for WBR (conventional techniques, segmental forward IMRT, inverse IMRT). Most centers use conventional tangential techniques (CTT) known as two opposite wedged photon fields for WBR. Conventionally, WBR is planned to a crude planning target volume consisting of the whole breast and treated by two tangential wedged beams. Although the usage of wedge increases the dose homogeneity, the use of wedged fields can result in a heterogeneous distribution, particularly in cranial and caudal parts of the breast, where low and high dose areas can occur. An overdosage may result in worse cosmetic results after irradiation and underdosage may result in a lower tumor control probability. There can be a significant variability in the total dose delivered to the lumpectomy site, particularly in women with large breasts. Recently, inverse IMRT techniques have been started to be used frequently in whole breast radiotherapy and studies, the use of intensity modulated radiotherapy (IMRT) to treat the whole breast after breast-conserving surgery has been shown to improve both dose homogeneity and target coverage, as well as to reduce the dose to normal tissues compared to a conventional tangential technique CTT.[1–9] Another advantage of using the IMRT technique may be expected especially in cases where large parts of the lung and the heart are covered with high dose using conventional treatment. Doses to the lung and the heart must be kept as low as possible to avoid long-term complications, since most patients have long life expectancy. With the usage of IMRT, this can lead to reduced toxicity and late effects as compared to conventional tangential technique.[10–13] Studies demonstrate increased mortality rate from myocardial infarction and ischemic heart diseases among irradiated patients with left-sided breast cancer as compared to similar patients with right sided breast cancer.[14–18] A possible disadvantage of using IMRT is the increased scatter dose to the organs at risk (OAR) such as the contralateral breast.[3]

The purpose of this study was to improve dose distribution to the left breast in order to determine the dose received by the ipsilateral lung, the heart, the contralateral lung and the contralateral breast during primary left-sided breast irradiation by using IMRT techniques compared to CTT. We have used several different numbers of IMRT beams and CTT for this comparison.

There are some studies showing that target volume coverage is increased while the dose to organs at risk (such as heart and lungs) reduced with increased number of beams in IMRT.[1,3] In our study, we researched the effect of increased numbers of beams on heterogeneity index (HI), conformity index (CI) and OAR dose in IMRT and the effects of HI, CI and OAR dose. Positive and negative effects of increased number of the beams are discussed. In addition, HI, CI and OAR dose impact was researched according to breast volume.

2. Materials and methods

2.1. Patients

Thirty patients with early stage, left-sided breast cancer that had been previously treated with radiation therapy by using CTT after a breast conserving surgery were selected to compare different treatment planning techniques. All patients had American Joint Committee on Cancer (AJCC) pathologic Stages I–IIA (T1–T2 N0) infiltrating ductal carcinoma of the breast. The patients' mean age was 49 years old. Patients with radiotherapy to the axillary or supraclavicular lymph nodes were not included in this study.

All patients underwent a computer tomography (CT) scan at 5-mm intervals using Siemens Biograph Duo LSO combined PET-CT scanner. Patients were positioned supine on a breast board with the left arm elevated above the head and the head turned to the right equivalent to the treatment position. CT axial images were obtained of the area extending from the underside of the chin to the upper abdomen, including the entire bilateral lungs and heart.

2.2. Target volume and organs at risk (OAR) definition

The CT axial images were transferred to our contouring workstation (Focalsim) for the target volumes and the OAR to be delineated by the radiation oncologist. The breast tissue (clinical target volume [CTV]) was defined as a target volume and the contralateral breast, ipsilateral lung, contralateral lung and heart tissues as OAR (Fig. 1). The heart was defined as all the visible myocardium and pericardium, from the apex to the right auricle, atrium and infundibulum of the ventricle. The lungs were contoured automatically on CT scans. CTV is defined medially at the lateral edge of the sternum, inferi-