Int. J. Radiation Oncology Biol. Phys., Vol. 82, No. 5, pp. 1698–1705, 2012

0360-3016/$ - see front matter

doi:10.1016/j.ijrobp.2011.02.058

PHYSICS CONTRIBUTION

A COMPREHENSIVE ANALYSIS OF CARDIAC DOSE IN BALLOON-BASED HIGH-DOSE-RATE BRACHYTHERAPY FOR LEFT-SIDED BREAST CANCER

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Purpose: To investigate radiation dose to the heart in 60 patients with left-sided breast cancer who were treated with balloon-based high-dose-rate brachytherapy using MammoSite or Contura applicators.
Methods and Materials: We studied 60 consecutive women with breast cancer who were treated with 34 Gy in 10 twice-daily fractions using MammoSite (*n* = 37) or Contura (*n* = 23) applicators. The whole heart and the left and right ventricles were retrospectively delineated, and dose–volume histograms were analyzed. Multiple dosimetrics were reported, such as mean dose (D_{mean}); relative volume receiving 1.7, 5, 10, and 20 Gy (V1.7, V5, V10, and V20, respectively); dose to 1 cc (D_{1cc}); and maximum point dose (D_{max}). Biologic metrics, biologically effective dose and generalized equivalent uniform dose were computed. The impact of lumpectomy cavity location on cardiac dose was investigated.
Results: The average ± standard deviation of D_{mean} was 2.45 ± 0.94 Gy (range, 0.56–4.68) and 3.29 ± 1.28 Gy (range, 0.77–6.35) for the heart and the ventricles, respectively. The average whole heart V5 and V10 values were 10.2% and 1.3%, respectively, and the heart D_{max} was >20 Gy in 7 of 60 (11.7%) patients and >25 Gy in 3 of 60 (5%) patients. No cardiac tissue received ≥30 Gy. The V1.7, V5, V10, V20, and D_{mean} values were all higher for the ventricles than for the whole heart. For balloons located in the upper inner quadrant of the breast, the average whole heart D_{mean} was highest. The D_{mean}, biologically effective dose, and generalized equivalent uniform dose values for heart and ventricles decreased with increasing minimal distance from the surface of the balloon.
Conclusions: On the basis of these comprehensive cardiac dosimetric data, we recommend that cardiac dose be routinely reported and kept as low as possible in balloon-based high-dose-rate brachytherapy treatment planning for patients with left-sided breast cancer so the correlation with future cardiac toxicity data can be investigated. © 2012 Elsevier Inc.

Cardiac dose, Heart, High-dose-rate brachytherapy, Balloon, MammoSite, Contura.

INTRODUCTION

Accelerated partial breast irradiation after lumpectomy is currently being compared with whole breast irradiation (WBI) after breast-conserving surgery in the National Surgical Adjuvant Breast and Bowel Project B-39 / Radiation Therapy Oncology Group 0413 Phase III trial (1). Intracavitary balloon-based high-dose-rate (HDR) brachytherapy is one of three accelerated partial breast irradiation techniques permitted on the protocol along with three-dimensional conformal external-beam radiation therapy (3D-CRT) and interstitial brachytherapy. Guidelines for off-protocol use have recently been defined for selected low-risk patients (2).

In balloon-based breast HDR brachytherapy planning, organs at risk (OARs) include the skin and ribs adjacent to the lumpectomy cavity; radiation dose to these structures should be monitored and reduced if possible (3). In selected patients with left-sided lesions, the HDR balloon can be located near the heart, which may result in clinically relevant cardiac doses. Although dose limitations for the heart are available for 3D-CRT (1), to our knowledge cardiac dose guidelines have not been described for balloon-based HDR brachytherapy planning.

In patients treated with WBI, late cardiac toxicity is of significant concern because it may result in an increase of up to 27% in cardiac mortality in breast cancer survivors compared

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Presented in part at the 2010 American Brachytherapy Society Annual Meeting, Atlanta, GA, April 29–May 1, 2010, and in part at the 52nd American Society for Radiation Oncology Annual Meeting, San Diego, CA, October 31–November 4, 2010.

Conflict of interest: none.

Acknowledgment—The authors thank Katsiaryna Mazurenka, M.A., for statistical consultation.

Received Oct 27, 2010, and in revised form Feb 14, 2011. Accepted for publication Feb 22, 2011.

with patients treated without irradiation (4). For patients who received WBI, left-sided tumor laterality predicted a higher mortality from heart disease (5). The dose–response relationship for cardiac irradiation in breast cancer is being studied (6), and evaluation of methods for limiting heart dose is a focus of ongoing research (7).

Cardiac dose in balloon-based breast brachytherapy has been investigated (8–13). The major limitations of the available studies were the low numbers of patients (8, 11–13), the inclusion of only limited dose–volume histogram (DVH) data points (9–13), and the use of simulated MammoSite plans for dose analysis in patients treated with 3D-CRT (9). The purpose of this study was to further investigate radiation dose to the heart for patients with left-sided breast cancer who were treated with balloon-based HDR brachytherapy using MammoSite or Contura applicators.

METHODS AND MATERIALS

Patient cohorts

Sixty consecutive patients with small (<3 cm) invasive or noninvasive carcinoma of the left breast were treated in our institution. All women were treated with HDR brachytherapy using either the single-lumen MammoSite catheter (Hologic, Marlborough, MA) (*n* = 37) or the multilumen Contura applicator (SenoRx, Irvine, CA) (*n* = 23). Before receiving brachytherapy, all patients underwent partial mastectomy with histologically negative margins. The median duration of clinical follow-up was <6 months. The study was approved by the Institutional Review Board.

Treatment planning and delivery

All patients were treated with the prescribed dose of 34 Gy in 10 twice-daily fractions delivered at least 6 hours apart over 5 consecutive working days using a remotely afterloaded HDR Ir-192 source. Treatment planning was performed according to the National Surgical Adjuvant Breast and Bowel Project B-39 / Radiation Therapy Oncology Group 0413 protocol guidelines using computed tomography (CT) images taken with 2 mm slice thickness for Contura patients or 3 mm for MammoSite patients. The dose was prescribed to the planning target volume for evaluation (PTV_EVAL), which was created as a uniform 1-cm expansion from the balloon surface, excluding the breast tissue within 5 mm from the skin surface, the chest wall, and the pectoralis muscle. For all patients, the multiple dwell position method (14–17) was used together with a surface optimization technique (17, 18) available in a commercial treatment planning system (BrachyVision version 8.1.20, Varian Medical Systems, Charlottesville, VA) to improve the target coverage (14–18). For Contura patients, the dwell time distribution for multiple lumens was optimized to reduce the maximal skin dose to <125% of the prescribed dose and the maximal rib dose to <145% of the prescribed dose while maintaining the required PTV_EVAL coverage (≥95% of PTV_EVAL included within 95% isodose line). On the planning CT, the shape and location of the balloon were reviewed, and the balloon diameter and skin spacing were measured. These measurements were verified on the simulation CT images taken before each treatment fraction.

Physical dosimetry

The planning CT images were acquired to encompass the entire bilateral breasts and the entire heart without intravenous contrast medium. The whole heart and the combined left and right cardiac ventricles were retrospectively delineated by a radiation oncologist. The left ventricle was not separately contoured because accurate delineation of the interventricular septum requires contrast-enhanced CT (19). The superior border of the heart was defined on the first CT slice below the bifurcation of the pulmonary arterial trunk, and the external border was set at the visceral pericardium. Figure 1 shows two-dimensional contours of the heart and the combined ventricles. For both structures, a DVH was generated, and the minimal distances from balloon to the heart, ventricles, and rib were measured. Cumulative DVHs (cDVHs) of the whole heart and the combined ventricles were evaluated, and multiple dosimetry points were reported such as mean dose (D_{mean}), relative volumes of interest receiving 1.7 (5% of the prescribed dose), 5,

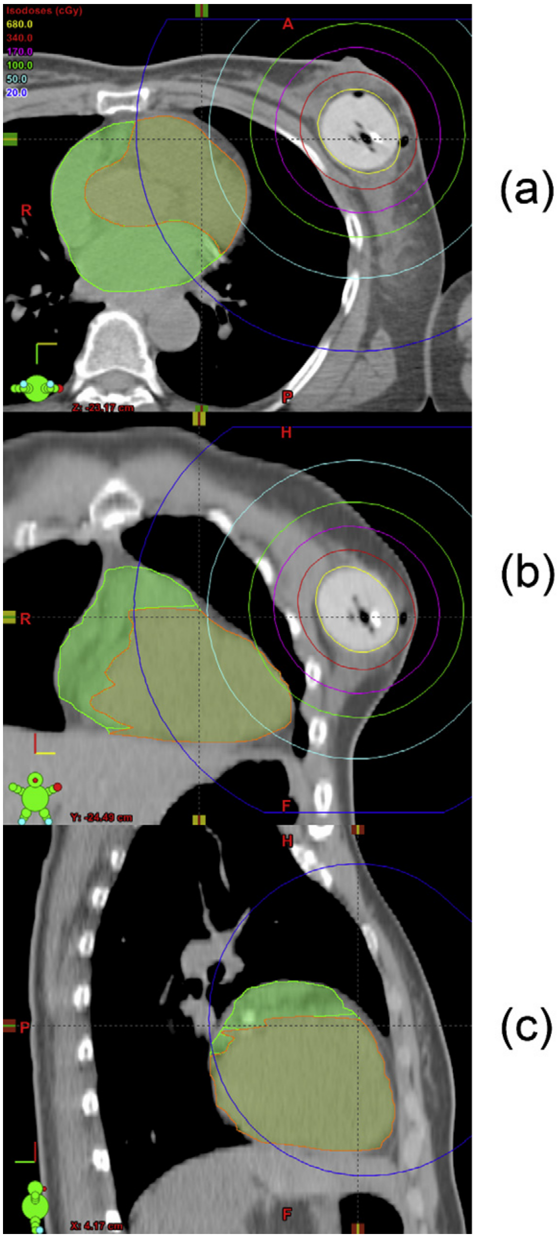

Fig. 1. Example of delineation of the whole heart and the combined ventricles on the axial (a), coronal (b), and sagittal (c) planes.