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Breast cancer radiotherapy

A dosimetric study of cardiac dose sparing using the reverse semi-decubitus technique for left breast and internal mammary chain irradiation

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ABSTRACT

Background and purpose: Breath-hold techniques can reduce cardiac dose in breast radiotherapy. The reverse semi-decubitus (RSD) technique is an alternative free-breathing method used at our centre. This study compares the dosimetry of free-breathing supine, RSD and moderate deep inspiration breath-hold (mDIBH) techniques.

Materials and methods: Twelve patients with left-sided breast cancer who were simulated using standard supine, RSD and mDIBH techniques were identified retrospectively. New plans using standard breast tangents and techniques for internal mammary chain (IMC) nodal coverage were assessed.

Results: Using standard tangents, mean heart dose, heart V_{25Gy} and mean left anterior descending artery (LAD) dose were found to be significantly lower for RSD and mDIBH when compared to free-breathing supine ($p \leqslant 0.03$). Using wide-tangents, the maximum LAD point dose was also lower for RSD and mDIBH ($p \leqslant 0.02$). There were no statistically significant dosimetric differences found between the RSD and mDIBH simulation techniques for standard breast-tangent plans, though organ-at-risk doses were lower for mDIBH in wide-tangent plans. There was no improvement in cardiac dosimetry between RSD and free-breathing supine when using an electron field IMC plan.

Conclusions: For patients unable to tolerate breath-hold, the RSD technique is an alternative approach that can reduce cardiac dose.

Several studies have shown an increase in the rate of ischaemic heart disease after adjuvant radiotherapy for left-sided breast cancer [1–6]. The inclusion of the internal mammary chain within the treatment volume has also been associated with increased late heart toxicity [7,8]. Important dosimetric factors related to cardiac events include mean heart dose, the volume of heart receiving 25 Gy or more (heart V_{25Gy}), as well as the dose to coronary arteries. Therefore, efforts have been made to develop simulation and treatment techniques in order to reduce the volume of cardiac irradiation, in particular when treating the left side.

Techniques that have been shown to improve cardiac dosimetry over the standard supine free-breathing method include: isocentric lateral decubitus (ILD) [9,10], prone [11–13], voluntary deep inspiration breath-hold (vDIBH) [14–16], active breathing control (ABC) [17–20] and partial breast irradiation [21,22] in selected cases. However, certain factors may preclude their use, such as intolerance of the technique by the patient, the requirement for specialized equipment, and clinical factors such as the inclusion of the internal mammary chain or regional lymph nodes in the desired treatment volume.

In this retrospective dosimetric study, we describe a novel free-breathing technique for left-sided breast and chest wall irradiation in the reverse semi-decubitus (RSD) position. The effect of RSD on cardiac and lung dose sparing is compared to supine and mDIBH techniques. Standard breast tangents, wide tangents including the internal mammary chain (IMC) lymph nodes and standard tangents with an electron field for the IMC lymph nodes are evaluated.

Methods and materials

Patient selection and simulation technique

After study approval by the institutional research ethics board, twelve patients were identified who underwent CT simulation for adjuvant breast or chest wall irradiation between November 2012 and December 2013 at our centre. During the study period,

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the institutional standard protocol was to simulate all patients who were shown to have unfavourable cardiac anatomy after supine simulation in both RSD and mDIBH. Therefore, all patients included in the current study had simulation scans in free-breathing supine, RSD and moderate deep inspiration breath-hold (mDIBH). Supine simulation was performed according to our institutional protocol, with the patient free-breathing on a breast-board.

Prior to mDIBH simulation, a coaching session using the ABC spirometry equipment was performed to ensure the patient was able to tolerate the apparatus, and hold their breath for a minimum of 15 s. This also provided a measurement of the maximal inspiratory capacity of each patient. The patient then underwent CT simulation in the supine position on a breast-board. The ABC breath-hold threshold was set to 80% of the maximal inspiratory capacity.

RSD simulation was performed by rotating the patient into a semi-lateral decubitus position, with the right side towards the treatment couch and the left side elevated. The patient's arm was abducted to an angle of 70–110°, and they were immobilized using a vacuum bag device. The simulation and treatment are performed free-breathing (Fig. 1).

Target definition and organs at risk

Using the cardiac atlas by Feng et al. [23], the heart was delineated along with the left anterior descending coronary artery (LAD) up to its origin at the aortic root. A 6 mm diameter contouring tool was used to outline the LAD [24]. All visible lung tissue was contoured, excluding the trachea, main bronchus and large hilar vessels.

Internal mammary chain target delineation and treatment techniques were adopted directly from a large, randomized, multi-centre study of regional nodal irradiation [25]. The IMC nodal volume was defined as 1 cm around the internal mammary vessels in the first to third interspaces, limited by the sternum and the pleural-lung interface.

Planning process

To allow for dosimetric comparison of different clinical presentations, multiple radiation plans were created for each CT simulation. This included treatment of the whole breast/chest wall alone using standard tangents (36 plans), as well as treatment of the whole breast in addition to the IMC nodal volume using both the modified wide-tangent (36 plans) and internal mammary electron field techniques (24 plans). Strict anatomic field limits were followed in order to maintain comparable treatment volumes between scans.

The standard breast tangent field borders were the sternum medially and the anterior aspect of the latissimus dorsi muscle laterally. The superior and inferior borders were the inferior aspect of the clavicular head and 1.5 cm below the infra-mammary fold respectively. The treatment baseline extends from the mid-sternum to the anterior aspect of the latissimus dorsi muscle (Fig. 2).

The modified wide tangent technique included a medial border 3 cm contralateral to the mid-sternum. The other field limits are as described in the standard breast tangent technique. Cardiac and lung shielding was placed in the inferior and posterior aspect of the field, ensuring that coverage of the IMC nodal volume, breast and chest wall was not compromised (Fig. 2) [25].

In the internal mammary electron field technique, the tangent fields were as described for standard breast tangents, but the medial border was approximately 5 cm ipsilateral from the mid-sternum. An electron field was placed with a medial border 1 cm contralateral to the mid-sternum, and matching the medial border of the tangents laterally (to include the IMC nodal volume). Inferior and superior borders also matched the tangent field. The gantry angle for the electron field was 5° less than the medial tangent [25]. Electron plans were only developed for supine free-breathing and RSD simulations due to practical issues regarding the feasibility of the electron field technique with mDIBH in the clinical setting.

A dose of 5000 cGy in 25 fractions was prescribed for each scan. When being targeted, 100% of the IMC nodal volume was covered by 80% of the prescribed dose [25]. Coverage of the breast target volume was optimized, ensuring a dose homogeneity of ±7% of the prescription. Sample dose distributions are provided in Fig. 3 for each beam arrangement using the RSD technique.

Statistical analysis

Using the Pinnacle[3] (Philips Medical Systems) treatment planning system, dose–volume histograms were calculated for each of the treatment plans. Volume, mean dose and maximum dose were recorded for the heart, LAD and lung for each plan. The heart V25Gy, lung V5Gy and total lung volume were also evaluated.

SPSS 17.0 software (SPSS Inc., Chicago, IL) was used to compare dose parameters between the three simulation techniques using one-way analysis of variance (ANOVA). A p-value of $\leqslant 0.05$ was considered statistically significant. The non-parametric paired Wilcoxon signed-rank test was used for post hoc analysis.

Results

Of the 12 identified patients, 6 had undergone mastectomy and 6 had breast conserving surgery. A total of 36 CT simulations were performed. Table 1 provides a summary of the average dose parameters for the heart, LAD and lung using free-breathing supine, RSD and mDIBH simulation techniques for the standard breast tangent and wide-tangent plans. Based on CT simulation, the mean total lung volume for the mDIBH technique was 4.5 L. This was significantly larger than the free-breathing techniques, which both had a mean lung volume of 2.5 L ($p = 0.002$).

In standard supine and wide-tangent plans, one-way analysis of variance showed a significant effect of simulation technique on mean heart dose, heart V25 Gy (percent and absolute) and LAD mean dose ($p < 0.001$–0.02). There was also a significant effect on maximum point dose to the LAD in the wide-tangent treatment plans. There was no significant effect found for lung V20 Gy or V5 Gy.

Treatment plans including IMC coverage

Post-hoc analysis of wide-tangent plans showed that mDIBH provided superior heart and LAD sparing for all of these dose parameters as compared to both supine and RSD ($p = 0.002$–0.006). In addition, RSD was superior to supine in all cases ($p = 0.002$–0.02). These results are summarized in Table 1. Relative dose reductions from the free-breathing supine technique in wide-tangent plans were significantly larger for mDIBH as compared to RSD for the mean heart dose (63.1% vs. 41.6%, $p = 0.003$), heart V_{25Gy} (86.2% vs. 53.6%, $p = 0.002$), mean LAD dose (55.6% vs. 26.3%, $p = 0.002$) and maximum point dose to the LAD (21.1% vs. 7.5%, p = 0.006). 2 patients had a 100% reduction in the heart V25 Gy using mDIBH.

Paired comparison of the electron field plans did not show any statistically significant dosimetric differences in organ-at-risk dose between standard supine and RSD plans ($p \geqslant 0.08$). In standard supine plans, mean heart dose, heart V25 Gy, LAD mean dose and maximum dose to the LAD were 8.4 Gy, 9.1%, 2.6 Gy and 4.6 Gy respectively. In RSD plans, these were 7.3 Gy, 6.9%, 2.8 Gy and 4.6 Gy respectively.