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Original paper

In-vivo dosimetry comparison of supraclavicular junction dose for breast and chest-wall patients with and without deep inspiration breath hold (DIBH)

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ABSTRACT

Purpose: The use of deep inspiration breath-hold (DIBH) for patients with left-sided breast cancer reduces cardiac dose, with the aim of reducing the risk of major coronary events. However, this technique has not been universally adopted for patients requiring regional nodal irradiation (RNI) with one concern related to the junction dose. This study evaluates the dose received at the junction for both DIBH and free-breathing patients having tangential breast/chest wall radiation and regional nodal radiation treated with 3D-conformal or hybrid IMRT radiotherapy.

Methods: In-vivo dosimetry measurements utilizing EBT3 GafChromic™ film were performed for 19 patients during three fractions over their course of treatment. The mean junction dose and variability in junction dose were compared between the DIBH and free breathing patients.

Results: Our results show that for voluntary DIBH (v-DIBH) patients the junction dose is more variable between fractions. However, when comparing the average junction dose for DIBH and free breathing patients over the three measurements, the difference was small and not statistically significant. A larger difference was seen when patient measurements were analysed based on treatment linac.

Conclusions: These results show that the mean junction dose is not significantly compromised by the use of v-DIBH. The small possibility of a change in junction dose due to breathing technique should be weighed against the proven increased risks associated with excess cardiac dose received by free-breathing patients. If junction dose is of concern, an in-vivo study, such as this one, could allow cautious introduction of DIBH for patients requiring supraclavicular irradiation.

1. Introduction

In recent years, relative survival rates after diagnosis of breast cancer in women have increased. Between the periods 1982–1987 and 2006–2010, five-year relative survival increased from 72% to 89.4% in Australian women [1]. The projected 5-year survival rate for 2015 is 90% [2].

However, the survival benefit from radiotherapy after breast conserving surgery is offset by a 1% increase in non-breast cancer mortality at 15 years and 90% of this cardiovascular in origin [3]. A progressive relationship between the dose and the risk of subsequent cardiac toxicities has been suggested in current literature [3–6].

Darby et al, have quantified major coronary events (MCE) in women who had breast radiotherapy in Denmark and Sweden between 1958 and 2001 [7]. They show a strong linear relationship between mean heart dose (Gy) and subsequent MCE, with MCE increased at 7.4% per Gy of mean heart dose [7]. These results suggest that all women would benefit from heart-sparing radiotherapy.

Using Deep Inspiration Breath Hold (DIBH) during the delivery of radiotherapy is an established technique to reduce dose to cardiac structures. DIBH involves taking a deep breath in and then holding for a set period of time during radiotherapy delivery. This causes the diaphragm to descend, and the heart to move away from the breast and chest wall (posterior and inferior displacement of the heart). The implementation of DIBH during radiotherapy for left sided breast cancer has shown a reduction of the dose to the heart and the left anterior descending artery (LAD) in a several trials [8–11] and is now a commonly used technique [12].

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Different variations of DIBH have been successfully implemented utilising gating based on infrared marker blocks (Varian RPM™) [10], active breath-hold where air flow is externally controlled (Elekta ABC™) [9], surface monitoring [13] or voluntary breath-hold (v-DIBH) based on an external reference such as light field or laser [11,14]. However, many of the challenges present in DIBH treatment are common to all these techniques including concerns over the dose received at the junction between the tangent and supraclavicular treatment fields.

Several treatment planning studies show that patients requiring supraclavicular and post-axillary nodal irradiation in conjunction with breast or chest wall radiotherapy would also benefit from the use of DIBH [15–17]. In addition, many institutions use DIBH for these patients routinely [14,18–21]. In a recent planning study by Yeung et al., the patients planned to receive regional nodal irradiation (RNI) had a greater reduction in mean heart and lower anterior descending artery (LAD) dose compared to patients receiving whole breast radiotherapy alone [22].

However, much of the literature on breast radiotherapy with DIBH does not include RNI. In a recent review by Latty et al. [23], which considered 18 DIBH studies, they found only 4 included irradiation of the supraclavicular fossa or axilla. Also in 2015, Smith et al. [24] found 2 of 8 studies included irradiation of the supraclavicular fossa and only 1 included irradiation of the axilla.

This focus of the simpler breast-only treatments may be due to a perceived difficulties associated with junctioning the radiation beams for patients while using the DIBH technique. Inhomogeneous dose at the junction can lead to recurrence and complications [25] and the use of DIBH may change the dose received at the junction. However, there is no published data evaluating the junction dose for DIBH patients. Therefore, patients may be being excluded from using DIBH and potentially receiving addition radiation to the heart unnecessarily.

In this paper, we evaluate the homogeneity and reproducibility of the dose at the junction for breast patients. In-vivo dosimetry measurements were performed for both free breathing and voluntary DIBH (v-DIBH) patients treated over a 6-months period to allow a comparison of the two techniques.

2. Method and materials

2.1. Patient selection and treatment technique

Data were obtained for 19 consecutive breast and chest-wall patients who were also having RNI in early 2017. One patient declined the invitation to participate. All patients had a radical course of treatment planned using conventional fractionated radiation at 1.8–2.0 Gy per fraction. All patients had radiation therapy to the breast/chest wall with regional nodal radiation based on institutional guidelines. Patients having breast conservation therapy were planned with a hybrid-IMRT/SIB technique [26] and chest wall treatments were planned using tangential fields with a field in field (FIF) static technique. Patients were treated with v-DIBH or free-breathing based on a clinical assessment by the radiation oncologist. As a result of this, all v-DIBH patients involved in this study were having treatment to the left breast or left chest-wall.

All patients were CT planned using the Varian Eclipse™ V13 treatment planning system with the AAA dose calculation algorithm. Patient treatments were delivered on a 21EX, 21IXS or 6EX Varian linear accelerator. Treatments were planned by a range of dosimetrists and the plans approved by one of two radiation oncologists. All patients were treated in a Supine position following the departmental breast and imaging protocols.

A v-DIBH technique was used for all patients, where a mark on the patient's skin was referenced to the in-room lasers to monitor the patient's breathing during treatment [11,14]. Treatments were verified using CINE images taken during irradiation. This technique has previously been described and verified in the literature [11,14].

2.2. Patient measurements

To determine the dose at the junction between the tangent and supraclavicular fields, an in-vivo dosimetry measurement was performed by placing EBT3 GafChromic™ film over the junction region for three separate treatment fractions.

The positioning of the film was determined relative to the patient tattoos prior to treatment in order to be centre on the junction both superiorly-inferiorly and laterally. The film pieces were placed on the patient's skin in the planned position and verified against the light field on treatment. For all patient fields planned without bolus, a 5 cm square of 1 cm thick bolus was placed over the film to avoid measuring dose close to the surface, where dose differences between the tangential and direct beams may be expected. For fields with planned bolus, no additional bolus was used. The film was secured to the patient and was left on the patient for all imaging and treatment fields in order to represent the actually patient junction dose receive during that fraction.

The measurements were performed over non-consecutive fractions and spread throughout treatment. On average, the number of fractions between measurements was 5.7 with a range of 2 to 14. Measurements were not made on the first day of treatment to avoid measuring on a day which may not be representative of the whole treatment course.

2.3. Film dosimetry

The in-vivo dosimetry measurements were taken using a single box of EBT3 GafChromic™ film and scanned on an Epson 10,000 XL scanner. For each measurement, 3 pieces of 5 cm square film were stacked and wrapped in thin plastic. The three films were then analysed separately and the results averaged to reduce uncertainty in the measurement. All films were scanned with a consistent orientation and positioned centrally on the scanner to reduce the effect of non-uniformity across the scanner.

A calibration curve was created to convert the red channel pixel value to dose with points at 0, 0.3, 0.6, 1, 1.3, 1.6, 2, 2.3 and 2.6 Gy and the calibration was verified for each sheet using two verification film pieces irradiated to 2 Gy from each film sheet used for patient measurement. Part way through the study a second calibration curve was needed to cover the higher junction doses seen for DIBH patient. This curve covered a higher dose range with dose points at 0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5 and 4 Gy. This curve was verified against the initial curve and used for patients where the film showed higher doses than covered in the initial calibration.

The initial calibration films were scanned 6 days after exposure and the high dose calibration films were scanned 4 days after exposure. All patient films were scanned 2 days or more after exposure. By ensuring all films were scanned more than 1 day post-exposure development differences should be less than 1% [27].

The film images were analysed in RIT™ software. The junction was visually identified as the maximum (for over-dose) or minimum (for under-dose) dose in the region of the junction and the dose to this point recorded as well as the dose 1 cm above and below the junction (Fig. 1). The percentage difference between the junction dose and the dose to the surrounding tissue was then calculated as the junction dose divided by the average of the dose above and below the junction. The percentage difference at the junction was averaged for the three films to give the junction difference for that fraction.

2.4. Statistical comparison

For each patient, the mean relative junction dose and the range of relative junction doses were calculated. The mean of the mean doses for each breathing technique was calculated to look for systematic changes in the junction dose. The mean of the range of doses was also calculated for v-DIBH patients and free breathing patients to test for changes in the variability of the junction dose. A two-tailed, unpaired Student's T-test