Abstract. Background/Aim: To assess if deep inspiration breath-hold (DIBH) technique achieved dose sparing for organs-at-risk in left breast radiotherapy patients in order to reduce long-term complications. Patients and Methods: DIBH and Free-breathing (FB) as a control, CT planning scans obtained for 28 left breast/chest wall (+/- supraclavicular field) patients treated January 2008-December 2013 were retrospectively re-contoured and re-planned. Organs-at-risk examined: lungs, left lung, heart and left anterior descending coronary artery (LADCA). Quantitative statistical analysis of plan dose differences was performed. Results: Lung dose was not affected by DIBH. Heart D_max reduced by 34.5% (FB=41.81Gy, SD=3.963Gy vs. DIBH=27.39Gy, SD=12.393Gy, p<0.000004). Heart D_mean reduced by 32.6% (FB=1.817 G y, SD = 0.627 G y vs. DIBH=1.224Gy, SD=0.344Gy, p=0.0000083067). LADCA D_max reduced by 47.8% (DIBH mean=15.56Gy, SD=10.62Gy vs. FB mean=29.82Gy, SD=10.05Gy, p=0.0000031, and LADCA D_mean by 52% (DIBH mean=5.23Gy, SD=1.94Gy vs. FB mean=10.88Gy, SD=3.95Gy p=0.0000036027. Amplitude depths were not correlated with dose reductions. Conclusion: DIBH significantly reduces heart and LADCA dose. Further research is required to evaluate potential long-term implications for patients treated DIBH.

Breast cancer accounts for over 20% of all cancer diagnoses internationally, being the most prevalent gynecological cancer following non-melanoma skin cancer (1). Optimal treatment and management is essential. Radiotherapy plays a key role in breast cancer management (2). Adjuvant radiotherapy has been shown to increase survival rates and reduce loco-regional recurrences (3, 4). Fisher et al. highlighted that radiotherapy, when used after breast-conservative surgery can reduce patients’ local recurrence risk by over 60%. Survival rates were also found to equal those of mastectomy patients (5). However, while radiotherapy effectively reduced cancer mortality, chronic long-term side-effect complications affected patients’ overall mortality and survival rates. Even though cancer mortality was decreasing, patients were dying as a result of treatment side-effects (6).

Cardiac complications such as myocardial infarction, congestive heart failure, coronary artery disease and ischaemia presented long-term post-radiotherapy (6). Pulmonary complications post-radiotherapy have also been investigated. Radiation pneumonitis has routinely been reported in 1-5% of patients and lung fibros es have even been documented (earlier techniques with excessive lung volumes in treatment fields) (7). Gagliardi et al. used the relative seriality model to analyze the complication probability of radiation pneumonitis (8). A strong dose volume effect was established for pneumonitis risk. It is important therefore to consider the dose volume relationship and mean lung dose, in order to quantify potential pneumonitis risk.

Contrastingly, evidence is conflicting regarding specific heart anatomy most vulnerable to inducing cardiac complications post-radiotherapy. Focus mainly considers induction of coronary artery disease, perfusion defects, pericarditis and ischaemic events as a result of coronary arterial dose, ventricular dose, the volume of heart irradiated, and patient-specific factors that influence increased cardiac dose on treatment.

With conventional tangential radiotherapy the volume of heart irradiated and heart volume within the treatment field may influence potential cardiac risk. The heart, left ventricle and pericardium may potentially receive doses from the technique used to deliver treatment. The coronary arteries may receive dose as a result of field arrangement.
and scatter effects, particularly given their anatomical location. They can be difficult to distinguish/contour accurately on current CT planning systems and further imaging techniques have been recommended such as IV contrast, magnetic resonance imaging and single positron emission computer tomography to achieve accurate delineation for examination of the dose they receive. Feng et al. developed a specific radiation oncology cardiac atlas to aid delineation of cardiac substructures (with and without IV contrast) to reduce contouring discrepancies and attempt standardization (9).

Until a direct link is established, it is imperative that current treatment techniques and methods such as DIBH, are investigated to minimize cardiac and pulmonary doses where it is possible, without compromising therapeutic dose.

Patients and Methods

Study design. Ethical approval was sought and granted from Trinity College Dublin and Beacon Hospital Research Ethics Committee. The study comprised of a retrospective historically treated patient cohort that received left breast/left chest wall +/- left supraclavicular radiotherapy between January 2008 and December 2013 as part of their cancer management.

Participant population. 56 treatment plans were created for 28 patients and each patient acted as their own control. Inclusion criteria dictated patients were female, aged 18 years or older and able to give informed consent, with a diagnosis of breast cancer that required left breast or left chest wall plus or minus left supraclavicular radiotherapy treatment. Both a free breathing and DIBH CT planning scan were also required for comparative purposes, hence patients must have been able to perform and maintain DIBH for a minimum of ten seconds, in order to acquire DIBH CT planning scan.

Data collection. Patients were immobilized supine via a breast-board or wing-board and vacuum bag if treating supraclavicular area, both arms up and knee-fix. A 16 head GE Lightspeed CT scanner using 2.5mm slice thickness was used and breathing was monitored using Varian Real-time Position Management (RPM) respiration synchronized imaging and treatment system versions 1.7-1.7.5.

Contouring. CT scans were contoured and planned by the lead investigator using Varian Eclipse Treatment Planning Software Version 11.031. Contours included the combined lungs, left lung, heart and LADCA. Feng et al.’s cardiac atlas guidelines and RTOG Breast Atlas Contours were followed (9, 10).

The lungs were auto-contoured using Eclipse wizard software and manually corrected accordingly on lung windows. The heart was contoured superiorly from below the arch of the aorta down to include all visible pericardium inferiorly. Contoured heart volumes agreed within 50cc between FB and DIBH scans. The LADCA was contoured superiorly extending from the left coronary artery and inferiorly down the interventricular groove adjacent to the left and right ventricles. The windowing level required significant adjustment to contour the LADCA, particularly in the heart apex at the inferior extent.

Treatment planning. 6MV field-in-field technique was used for all plans, with low weighted 15MV beams occasionally used as required. Supraclavicular field plans were mono-isocentric. Tangential field posterior borders were matched to reduce internal divergence, with no boost volumes planned. Departmental planning constraints used and adhered to were as follows:

• Heart: V40Gy ≤5%, V20Gy ≤10%, Dmax < 50 Gy
• Lung: V20Gy ≤20%.

The LADCA was not considered in plan optimization but dose to this structure was reported in all cases.

ICRU dose constraints were met for all treatment plans, with one patient exception (111.1% free-breathing (FB), 110% DIBH Plan Maximum (11). Plans were calculated using AAA calculation algorithm version 8.9.17 and prescribed between 40.05Gy-50Gy in 15-25 fractions respectively. Cardiac shielding (without compromising target dose) was performed on all plans. This ensured a true comparison between FB and DIBH plans, eliminating potential variance.

Data analysis. IBM SPSS Statistics Version 21.0 was used for data analysis. For each organ, the specific dose to each volume, D10% to D100% inclusive, was investigated to determine dose impact of DIBH versus FB. For comparative purposes, maximum dose (Dmax), mean dose (Dmean), V30Gy and V20Gy were also assessed (12-17). Paired student sample t-tests were used, examining dose differences between FB and DIBH plans for organs-at-risk. Pearson correlations were performed to assess relationships between variables. Differences in amplitude level and the dose impact were examined using independent sample t-tests. With multiple t-tests performed (75) a Bon Ferroni correction was carried out, to reduce potential statistical errors. The corrected significance level was p<0.00066667.

Results

Demographics. Patients’ age ranged between 37 and 75 years, with mean age being 57.39 years, SD=8.412. The majority of patients were between 50 and 60 years old.

<table>
<thead>
<tr>
<th>D%</th>
<th>FB</th>
<th>SD</th>
<th>DIBH</th>
<th>SD</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>28.886</td>
<td>13.368</td>
<td>24.111</td>
<td>12.718</td>
<td>0.052</td>
</tr>
<tr>
<td>10</td>
<td>10.124</td>
<td>10.013</td>
<td>8.147</td>
<td>6.612</td>
<td>0.134</td>
</tr>
<tr>
<td>20</td>
<td>3.262</td>
<td>5.342</td>
<td>2.445</td>
<td>1.263</td>
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<tr>
<td>30</td>
<td>1.205</td>
<td>0.830</td>
<td>1.156</td>
<td>0.482</td>
<td>0.627</td>
</tr>
<tr>
<td>40</td>
<td>0.659</td>
<td>0.264</td>
<td>0.689</td>
<td>0.220</td>
<td>0.400</td>
</tr>
<tr>
<td>50</td>
<td>0.244</td>
<td>0.127</td>
<td>0.279</td>
<td>0.120</td>
<td>0.085</td>
</tr>
<tr>
<td>60</td>
<td>0.147</td>
<td>0.132</td>
<td>0.136</td>
<td>0.075</td>
<td>0.660</td>
</tr>
<tr>
<td>70</td>
<td>0.082</td>
<td>0.112</td>
<td>0.067</td>
<td>0.060</td>
<td>0.470</td>
</tr>
<tr>
<td>80</td>
<td>0.026</td>
<td>0.044</td>
<td>0.028</td>
<td>0.043</td>
<td>0.607</td>
</tr>
<tr>
<td>90</td>
<td>0.014</td>
<td>0.030</td>
<td>0.009</td>
<td>0.022</td>
<td>0.120</td>
</tr>
</tbody>
</table>

SD, Standard deviation; All figures have been rounded to 3 decimals.
Invasive ductal carcinoma accounted for 64.3%, n=18 patients’ diagnoses and a further 14.3%, n=4 patients’ with ductal carcinoma in situ (DCIS). Invasive lobular carcinoma and inflammatory breast cancer each accounted for 3.6%, n=1 patient’s diagnosis, respectively. None of the sample had metastatic disease, however 25%, n=7 patients had 1 involved node and 14.3%, n=4 patients required supraclavicular irradiation. Grade 2 disease was reported in 60.7%, n=17 patients staging, while 21.4%, n=6 were Grade 3. Wide local excision had been performed on 57.1%, n=16 patients, however none reported any lung issues. Pre-existing hypertension was reported in 17.9%, n=5 patients and angina in 3.6%, n=1 patient.

The combined lungs. Participants’ lung volumes, significantly increased with DIBH (mean=4632.52 cm³, SD=796.13 cm³) compared to FB (mean=2866.61 cm³, SD=602.51 cm³), t(27)=–17.26, p=0.00000000000000021212. No significant dose differences were noted for any lung volumes regardless of technique (Table I). D mean was not affected by DIBH (mean=5.78%, SD=2.55%) vs. FB (mean=48.33 Gy, SD=3.45 Gy, t(27)=–17.26, p=0.00000000000000021212). No improvement was observed for V 30Gy (DIBH mean=48.37 Gy, SD=3.45 Gy vs. FB mean=48.33 Gy, SD=3.45 Gy, t(27)=–17.26, p=0.00000000000000021212). However, V 20Gy was significantly lower with DIBH (mean=5.62%, SD=2.55%) vs. FB (mean=10.88%, SD=4.39%, t(27)=–17.26, p=0.00000000000000021212).

Ipsi-lateral lung dose. Unsurprisingly, left lung results reflected the combined lungs’ evaluation with no notable dose differences observed between FB and DIBH (Table IV).
The left lung’s volume expansion increased significantly with DIBH (mean=2153.02 cm³, SD=414.62 cm³) vs. FB (mean=1293.98 cm³, SD=323.27 cm³), mean difference=859.04 cm³, SD=258.21 cm³, t(27)=-17.605, p=0.00000000000000025169.

Left lung D\text{mean} was similar regardless (FB mean=8.15 Gy, SD=3.74 Gy vs. DIBH mean=7.16 Gy, SD=2.38 Gy, mean difference=0.99 Gy, SD=2.19 Gy, t(27)=2.104, p=0.045, Table II).

The heart. Cardiac dose was reduced for all volumes using DIBH (significant reductions between D_{10\%} and D_{50\%}, inclusive, Table V). Heart D_{\text{max}} reduced 34.5% (FB mean=41.81 Gy, SD=12.393 Gy, mean difference=14.27 Gy, SD=5.66 Gy, t(27)=6.357, p=0.00000000000000025169).

D_{\text{mean}} considerably reduced using DIBH (mean=1.224 Gy, SD=0.344 Gy) versus FB (mean=1.817 Gy, SD=0.627 Gy) at 32.6%, mean difference=0.593 Gy, SD=0.493 Gy, t(27)=6.357, p=0.000 (Table II). A 90.4% volume reduction for heart V_{30\%} was not significant between FB (mean=0.47%, SD=0.13%) and DIBH (mean=0.045%, SD=0.177%), mean volume difference=0.43%, SD=1.058%, t(27)=2.128, p=0.043. Heart V_{20\%} experienced an 86.2% notable reduction using DIBH (mean=0.122%, SD=0.321%) vs. FB (mean=0.885%, SD=1.182%), mean difference=0.763%, SD=1.046%, t(27)=3.263, p=0.064. This was not significant, Table III. DIBH removed heart in the field for 28.6%, (n=8 participants). Overall, a 55.9% reduction in mean heart volume within the beam’s eye view was observed.

Left Anterior Descending Coronary Artery (LADCA). The LADCA experienced significant dose reductions for all volumes examined using DIBH, Table VI. LADCA D_{\text{max}} reduced by 47.83% using DIBH (mean=15.56 Gy, SD=10.62 Gy) vs. FB (mean=29.82 Gy, SD=10.05 Gy), mean difference=14.27 Gy, SD=15.13 Gy, t(27)=4.989, p<0.000031. LADCA D_{\text{mean}} reduced using DIBH (mean=5.23 Gy, SD=1.94 Gy) vs. FB mean=10.88 Gy, SD=3.95 Gy, mean difference=5.66 Gy, SD=3.94 Gy, t(27)=7.595, p<0.000000036027, giving a 52% reduction, Table II. Overall, DIBH proved beneficial to reduce LADCA dose.

Amplitude. Participants’ amplitude, defined as the measurement from baseline expiration to their breath-hold, ranged from 0.6 cm-2.8 cm. The most frequent sample amplitude was 2.0 cm, obtained by 14.3%, (n=4) participants. The sample mean amplitude was 1.614 cm, SD=0.55 cm. 50% of (n=14) participants had amplitudes
above 1.614 cm and 50% (n=14) below it, dividing the sample into high (>1.6 cm) and low (<1.6 cm) categories. Whether participants had a high or low amplitude was not found to be statistically relevant, amplitude dose effect was negligible for organs-at-risk, Table VII. Age and amplitude were established as having a significant relationship, such that as the participants’ age increased their amplitude decreased, r(26)=−0.474, p=0.011. However, while the relationship was significant its’ negative basis was not.

Lung volume expansion difference and amplitude had no detectable relationship, r(26)=0.199, p=0.311. Amplitude depth was not impacted by participants’ smoking history, r(26)=−0.245, p=0.209. Coincidentally, smoking history also had no relationship with lung expansion obtained between FB and DIBH, r(26)=0.048, p=0.808. Suffering from comorbidities was the only other variable, that had a relationship with amplitude, r(26)=0.416, p=0.028. Overall, amplitude level did not result in any significant impact for participants in relation to affecting dose received or volumes irradiated.

### Discussion

**The Combined Lungs & Ipsilateral Lung**

Participants’ overall lung volumes increased significantly with DIBH as expected. Minimal dose differences were noted for each technique, Tables III, IV. However, regardless of technique used the doses were statistically comparable. Combined lungs Dmean and left lung Dmean were comparable between techniques. Marks *et al.* highlighted mean lung dose as an important factor for induction of radiation pneumonitis (18). To limit radiation pneumonitis risk to ≤20% Marks *et al.* recommend using: V20Gv≤30-35% and mean lung dose Dmean≤20-23 Gy. The lungs had a mean dose range of 0.43-5.0 Gy for DIBH with an overall mean dose, Dmean=3.39 Gy, equating to reductions ranging between 83-85% less than Marks *et al.*’s suggested clinical data for ≤20% risk of radiation pneumonitis induction. Even the highest value for DIBH, D30Gv=5 Gy, was 75-78.3% less than Marks’ recommended level, ensuring participants within this study have a reduced risk of radiation pneumonitis. However, the mean lung dose was not improved enough between FB and DIBH to further reduce this risk. Correspondingly for V30Gv and V20Gv no significant advantage or disadvantage for the lungs was detected using DIBH versus FB, Table III.

The lungs have a strong dose-volume relationship to quantify potential complication risk. They can recover from small sections irradiated to high doses however, large volumes receiving dose compromises function and complications may result, highlighting their parallel organ-at-risk architecture (8). This may aid interpretation of results explaining why DIBH had no impact over FB. While a larger lung portion is potentially irradiated using DIBH, with lung expansion (significantly increased on breath-hold), there is less actual lung tissue within the irradiated volume resulting in similar lung dose overall.

Hayden *et al.* published similar results using DIBH (16). In contrast Swanson *et al.*, concluded that lung doses were reduced with moderate DIBH, particularly the left lung mean dose (9.08 Gy vs. 7.86 Gy, p<0.001), a relative reduction of 13% observed over FB treatment (13). Hayden *et al.* also used the RPM system, while Swanson *et al.* used active breathing control (ABC) which may account for result differences. ABC can influence patients’ lung volume expansion and diaphragm placement compared

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**Table VII. The effect of amplitude level (high versus low) on left breast radiotherapy organs-at-risk Dmax and Dmean treated DIBH.**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Amplitude category</th>
<th>Mean dose Gy</th>
<th>SD</th>
<th>Mean difference Gy</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lungs Dmax</td>
<td>High</td>
<td>48.77</td>
<td>2.58</td>
<td>0.80</td>
<td>0.506</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>47.97</td>
<td>3.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lungs Dmean</td>
<td>High</td>
<td>3.22</td>
<td>0.79</td>
<td>−0.33</td>
<td>0.468</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>3.55</td>
<td>1.45</td>
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</tr>
<tr>
<td>Left lung Dmax</td>
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<td>2.43</td>
<td>0.88</td>
<td>0.460</td>
</tr>
<tr>
<td></td>
<td>Low</td>
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<td>3.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left lung Dmean</td>
<td>High</td>
<td>6.84</td>
<td>1.64</td>
<td>−0.64</td>
<td>0.491</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>7.48</td>
<td>2.97</td>
<td></td>
<td></td>
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<tr>
<td>Heart Dmax</td>
<td>High</td>
<td>28.09</td>
<td>12.18</td>
<td>1.40</td>
<td>0.772</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>26.69</td>
<td>13.03</td>
<td></td>
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<tr>
<td>Heart Dmean</td>
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<td>1.20</td>
<td>0.44</td>
<td>−0.05</td>
<td>0.713</td>
</tr>
<tr>
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<td>Low</td>
<td>1.25</td>
<td>0.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LADCA Dmax</td>
<td>High</td>
<td>15.72</td>
<td>11.02</td>
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<td>0.938</td>
</tr>
<tr>
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<td>Low</td>
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<tr>
<td>LADCA Dmean</td>
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<td>2.36</td>
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<td>0.960</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>5.21</td>
<td>1.51</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SD, Standard deviation; Mean Difference, difference between high and low. All doses have been rounded to 2 decimals.
to RPM’s external surrogate tracking system. RPM does not impact on patients’ natural breathing cycle; be it diaphragm or chest wall based for motion. ABC impacts on patients’ breathing cycle and this could possibly influence the amount of lung tissue irradiated, causing hyperinflation, resulting in the reduction reported by Swanson et al. The lungs’ expansion with DIBH compensates for the potentially increased lung volume irradiated, as the irradiated tissue quantity overall is reduced by expansion. Consequently, comparable results for FB and DIBH treatments occur.

DIBH positively reduced heart dose, Table V. While D5% reduced by 47%, this was not significant. D10%–D50% inclusive, received significant dose reductions ranging between 12.7-27%. Cardiac dose sparing from DIBH, could potentially lead to long-term reductions in cardiac complications. Heart Dmax benefitted by reducing 34.5% with DIBH (FB mean=41.81 Gy, SD=3.963 Gy vs. DIBH mean=27.39 Gy, SD=12.393 Gy, p<0.000, Table II). Bruzzaniti et al. reported a superior Dmax reduction of 78% (19). However, full cardiac shielding was not specified in their treatment plans as was here, hence this may account for notable result discrepancy.

Heart Dmean was significantly reduced by 32.6% (FB mean=1.817 Gy, SD=0.627 Gy vs. DIBH mean dose=1.224 Gy, SD=0.344 Gy, p<0.000, Table II). This is below Hayden et al., Swanson et al. and Nissen et al.’s reported reductions of 43.5%, 40% and 48% respectively (16, 13, 15). Again, cardiac shielding was not specified within these studies, which may account for the discrepancy. Considering Darby et al. established a linear 7.4% increase in major cardiac events for every 1Gy increase in breast patients’ heart Dmean this is potentially important (20). A 1Gy reduction in heart Dmean could theoretically be clinically beneficial in reducing cardiac complications. Here, a mean difference of 0.593Gy was achieved between techniques which could impact reduction of major cardiac events, in line with Darby et al.

Heart V30Gy reduced by 90.4%, however this was not significant (FB mean=0.47%, SD=1.03% vs. DIBH mean volume=0.045%, SD=0.177%, p=0.043). This contrasts with Swanson et al.’s significant 88% reduction (FB 3.2% vs. DIBH 0.39%, p<0.001) and Hayden et al.’s 66% reduction, (FB 7.1% vs. DIBH 2.4%, p<0.0001) (13, 16). Equally, heart V20Gy also experienced a sizable 86.2% reduction (FB mean=0.885%, SD=1.182% vs. DIBH mean=0.122%, SD=0.321%, p=0.003). Again, this was deemed non-significant. In contrast, Nissen et al.’s V20Gy 70% reduction was significant (DIBH 2.3% vs. 7.8% FB, p<0.0001) (15).

Results here, reflect Swanson, Hayden and Nissen et al.’s reports however were not significant. When examining the volumes receiving 20/30 Gy between the studies, there is a major division due to use of cardiac shielding (without compromising target coverage). Plans without cardiac shielding may experience increased dose reductions between FB and DIBH. The statistical acceptance level used here, is also more conservative than the comparative studies.

LADCA irradiation, resulting from anatomical position, may aid risk determination of potential cardiac complications (21, 22). Left breast patients have increased cardiac complication risk compared to right (21-23). 70% of post-treatment cardiac abnormalities were localized in the LADCA by Correa et al. (21). Nilsson et al. established a direct link between left breast irradiation and increased LADCA stenosis, plus a relationship between high risk radiotherapy hotspots and coronary arterial stenosis (22). Therefore, LADCA dose consideration is imperative, to attempt reduction of cardiac complications.

Feng et al.’s cardiac contouring atlas was used to improve heart and LADCA delineation (9). However, Lorenzen et al. concluded that Feng’s guidelines did not reduce variation/contouring errors (24). In response, the LADCA’s were contoured separately to other organs-at-risk, case-by-case. They are difficult to contour and not always visible (e.g. at the heart base), hence guideline usage to reduce discrepancies. Exact LADCA dose-volume-constraints are difficult to establish at present, despite awareness of dose susceptibility. D10%–D100%, received significant reductions (Table VI), important given the LADCA’s serial architecture, it cannot tolerate small volumes, irradiated to large doses causing functional compromise. This potentially could link to the coronary disease complications Correa et al. and Nilsson et al reported (21, 22).

LADCA Dmax achieved a 47.83% reduction (mean=15.56 Gy, SD=10.62 Gy vs. FB mean=29.82 Gy, SD=10.05 Gy, p<0.000). A 52% reduction in LADCA Dmean also resulted (mean=5.23 Gy, SD=1.94 Gy vs. FB mean=10.88 Gy, SD=3.95 Gy, p<0.000), Table II. These results are comparable with Vikstrom et al.’s 56.8% Dmax reduction (38.7 Gy FB vs. 16.7 Gy DIBH) and 64.6% Dmean reduction (18.1 Gy FB vs. 6.4 Gy DIBH) (25). In contrast, Anzar et al. established LADCA DIBH Dmean=17.8 Gy SD=14 Gy contrasting with results here & Taylor et al.’s Dmean=12.0 Gy, SD=2.3 Gy for Swedish women treated in the 1990s using FB (26, 27). Anzar et al. suggests contouring and planning technique differences to explain the discrepancies, highlighting the importance of accurate LADCA contouring. Currently, LADCA dose complication risks are being researched in Scandinavia via the RACE study to establish potential dose volume constraints (28). LADCA dose may be a predictor of future coronary events and an important breast organ-at-risk.

Patients’ amplitude level had no impact on dose reduction for OARs, Table VII. Amplitude also had no relationship with lung volume expansion and was not affected by smoking history. Only age and co-morbidity history had significant relationships with amplitude depths. This illustrates the simplicity of the external surrogate respiratory system, being heavily influenced by location and patients’
chest motion. Patients’ breathing cycle dictates motion, emphasizing the importance of documenting surrogate location for reproducibility. The external motion depth recorded is not relatable to internal motion expansion occurring. Elderly, co-morbid patients may generally have shallower breathing cycles and this is evident here. It is a major drawback regarding lack of quantifiable influence, compared to ABC (13). However, comparatively it is less invasive and more tolerable for patients (16). Importantly, DIBH capability is achievable allowing potential OAR dose reduction.

Conclusion

DIBH reduces dose to the heart and LADCA, without increased dose to the combined or ipsi-lateral lungs. Amplitude is an independent factor that is not correlated with DIBH dose benefits. The LADCA should be routinely contoured, for evaluation of dose impact and long term complications. LADCA dose was most affected by DIBH. Further evaluation and collaborative research is required to establish LADCA dose volume constraints. Dose reductions achieved using DIBH may potentially lead to reducing long term cardiac complications from left breast radiotherapy. Further research and long term follow-up is recommended to establish the clinical effects of DIBH.

References


