Reproducibility in Prone Breast Cancer Treatments

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Overview

- Learning Objectives
  - Prone Setup for Breast Cancer Treatments
    - Why prone?
    - Benefits of a prone position setup to reduce toxicities
  - Prone Setup Procedures
    - Considerations for selecting a prone breast board
    - Currently available prone breast board options
    - How is setup performed?
  - Quality assessment project
    - Investigation in patient to breast board reproducibility using Cone-Beam CT Data
Breast Cancer

- About 1 in 8 women in the United States of America will develop invasive breast cancer over the course of her lifetime.
- In 2010, >200,000 women and >2,000 men were diagnosed with breast cancer in the US.
- Typically treated with some combination of surgery, chemotherapy, hormonal therapy, biological therapy, and/or radiation therapy.
- Patients undergoing radiation can be treated with brachytherapy and/or external beam radiation.
- With external beam radiation therapy, patients are typically treated for 5-30 days in a supine position, using a breast board for support and positioning.

Prone Setup for Breast Cancer Treatments

- With the advent of CT based planning, using a prone technique for breast cancer has become a feasible, if not an advantageous method for treatment.
Historically, this set up has been reserved for patients with large, pendulous breasts, to reduce the separation and amount of heart and lungs that radiation could potentially traverse through.

Prone Setup for Breast Cancer Treatments

- The NYU Langone Medical Center has established a long history of research on treating breast cancer patients using a prone technique; showing its potential to be beneficial in reducing acute and late toxicities.
- Treated >5,000 patients in this set up.
Prone Setup for Breast Cancer Treatments

Why prone?

- Reduce Lung and Heart involvement in treatment field
- Evidence for cardiotoxicity in breast radiotherapy
- Increased mortality from ipsilateral lung disease

Key strategy in excluding these vital organs without compromising target coverage

Long-term mortality from heart disease and lung cancer after radiotherapy for early breast cancer: prospective cohort study of about 300,000 women in US SEER cancer registries

Sarah C Darby, Paul McGale, Carolyn W Taylor, Richard Peto

Summary
Background Radiotherapy for early breast cancer can decrease breast cancer mortality but increase other mortality, mainly from heart disease and lung cancer. The mean cardiac dose from irradiation of a left-sided breast cancer can be two or three times that for a right-sided breast cancer. The mean ipsilateral (i.e., on the same side as the breast...
Prone Breast Cancer Treatments

- Investigated late morbidity
  - SEER registry data on 300,000 women
  - Cardiac Mortality Ratio for left sided treatment vs right sided treatment was 1.42 at 10-14 years and 1.58 at >15 years
  - Ipsilateral lung cancer death also significantly increased

ASSOCIATION BETWEEN TANGENTIAL BEAM TREATMENT PARAMETERS AND CARDIAC ABNORMALITIES AFTER DEFINITIVE RADIATION TREATMENT FOR LEFT-SIDED BREAST CANCER

Candace R. Correa, M.D.,* Indra J. Das, Ph.D., F.I.P.E.M., F.A.A.P.M., F.A.C.R.,* Harold I. Litt, M.D., Ph.D.,† Victor Ferrari, M.D.,‡ Wei-Ting Hwang, Ph.D.,§ Lawrence J. Solin, M.D.,* and Eleanor E. Harris, M.D.*

*Departments of Radiation Oncology, †Radiology-Cardiovascular Imaging Section, ‡Medicine-Division of Cardiovascular Medicine, and §Center for Clinical Epidemiology and Biostatistics, University of Pennsylvania, Philadelphia, PA

Purpose: To examine the association between radiation treatment (RT) parameters, cardiac diagnostic test abnormalities, and clinical cardiovascular diagnoses among patients with left-sided breast cancer after breast conservation treatment with tangential beam RT.

Methods and Materials: The medical records of 416 patients treated between 1977 and 1995 with RT for primary left-sided breast cancer were reviewed for myocardial perfusion imaging and echocardiograms. Sixty-two patients (62/416, 15%) underwent these cardiac diagnostic tests for cardiovascular symptoms and were selected for further study. Central lung distance and maximum heart width and length in the treatment field were determined for each patient. Medical records were reviewed for cardiovascular diagnoses and evaluation of cardiac risk factors.

Results: At a median of 12 years post-RT the incidence of cardiac diagnostic test abnormalities among symptomatic left-sided irradiated women was significantly higher than the predicted incidence of cardiovascular disease in the patient population. 6/62 (9%) predicted vs. 24/62 (39%) observed, p = 0.001. As compared with patients with normal tests, patients with cardiac diagnostic test abnormalities had a larger median central lung distance (2.6 cm vs. 2.2 cm, p = 0.01). Similarly, patients with vs. without congestive heart failure had a larger median central lung distance (2.8 cm vs. 2.3 cm, p = 0.008).

Conclusions: Contemporary RT for early breast cancer may be associated with a small, but potentially avoidable, risk of cardiovascular morbidity that is associated with treatment technique. © 2008 Elsevier Inc.
Prone Breast Cancer Treatments

- Investigated association between RT parameters, cardiac diagnostic test abnormalities, and clinical cardiovascular diagnoses
  - At median of 12 years post RT, incidence of abnormalities among left sided irradiated women was significantly higher than predicted incidence of cardiovascular disease in the patient population

Prone Breast Cancer Treatments

- Prone position as a solution?
- Prone position offers better sparing of lung and heart

Same Patient, Supine vs Prone

*Source: Silvia Formenti, MD; Seminars in Radiation Oncology, 2004*
Same Patient, Supine vs Prone

*Source: Silvia Formenti, MD; Seminars in Radiation Oncology, 2004
Reduced Respiratory Motion

- Intrafraction Motion: Supine
- Intrafraction Motion: Prone

*Source: Keith DeWyngaert, PhD; NYU Langone Medical Center
Prospective assessment of optimal individual position (prone versus supine) for breast radiotherapy: volumetric and dosimetric correlations in 100 patients.


Abstract

PURPOSE: Damage to heart and lung from breast radiotherapy is associated with increased cardiovascular mortality and lung cancer development. We conducted a prospective study to evaluate which position is best to spare lung and heart from radiotherapy exposure.

METHODS AND MATERIALS: One hundred consecutive Stage 0-IIA breast cancer patients consented to participate in a research trial that required two computed tomography simulation scans for planning both supine and prone positions. The optimal position was defined as that which best covered the contoured breast and tumor bed while it minimized critical organ irradiation, as quantified by the in-field heart and lung volume. The trial was designed to plan the first 100 patients in each position to study correlations between in-field volumes of organs at risk and dose.

RESULTS: Fifty-three left and 47 right breast cancer patients were consecutively accrued to the trial. In all patients, the prone position was optimal for sparing lung volume compared to the supine setup (mean lung volume reduction was 93.5 cc for right and 103.6 cc for left breast cancer patients). In 46/53 (87%) left breast cancer patients best treated prone, in-field heart volume was reduced by a mean of 12 cc and by 1.8 cc for the other 7/53 (13%) patients best treated supine. As predicted, supine-prone differences in in-field volume and mean dose of heart and lung were highly correlated (Spearman’s correlation coefficient for left breast cancer patients was 0.90 for heart and 0.94 for lung and 0.92 for right breast cancer patients for lung).

CONCLUSIONS: Prone setup reduced the amount of irradiated lung in all patients and reduced the amount of heart volume irradiated in 87% of left breast cancer patients. In-field organ volume is a valid surrogate for predicting dose; the trial continued to the planned target of 400.

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NYU 05-181: Optimal Positioning Trial

- Internal breast treatment protocol
- Patients positioned both prone and supine to select optimal individual positioning based on the least heart and lung volume in the beam’s eye view

*Source: Lymberis, Prospective assessment of optimal individual position (prone versus supine) for breast radiotherapy: volumetric and dosimetric correlations in 100 patients., Int J Radiat Oncol Biol Phys. 2012 Nov 15;84(4):902-9
Left Breast: Supine versus Prone

*Source: Lymberis, Prospective assessment of optimal individual position (prone versus supine) for breast radiotherapy: volumetric and dosimetric correlations in 100 patients., Int J Radiat Oncol Biol Phys. 2012 Nov 15;84(4):902-9
NYU 05-181: Optimal Positioning Trial

- Optimally spare heart and lung while assuring same coverage of breast
- Prone better 100% in right Breast Ca and in 85% of left Breast Ca

*Source: Formenti, Prone vs supine positioning for breast cancer radiotherapy, JAMA. 2012 Sep 5;308(9):861-3
NYU 05-181: Optimal Positioning Trial

- Prone significantly improved limiting lung and heart exposure independent of breast size*.

### Table. Differences in Volumes of Heart and Lung Between Supine and Prone Positions by Breast Volume and Right vs Left Breast Cancer

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<tr>
<th>Breast Volume, cm³</th>
<th>No.</th>
<th>Supine</th>
<th>Prone</th>
<th>Difference of Supine Minus Prone</th>
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<th>Prone</th>
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<td>(80.16 to 99.55)</td>
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*There was no in-field heart volume in any of the patients with right breast cancer.

*The 95% CIs are based on paired t-statistics.

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*Source: Formenti, Prone vs supine positioning for breast cancer radiotherapy, JAMA. 2012 Sep 5;308(9):861-3*
Prone Setup Procedures

- How is setup performed?
  - Breast Board Considerations
  - Available Breast Boards
  - Set up procedures for reproducibility
Considerations

- **Breast Board Height**
  - Will patients fit through CT Scanner and reliably reconstruct the surface?
    - Local Patient Population
    - CT Bore size

- **Arm Support**
  - Stability
  - Out of Beam Path
Considerations

- CT Artifacts from edge of board
Considerations

- Accommodating L/R sided treatments
- Head Position
  - Side tilt versus “massage-table” setup
Considerations

- Patient Rotation
  - Wedging into Breast Opening
Considerations

- Indexing
- Couch angles and collisions
- Compatibility with CBCT
- Buildup effects due to material intercepted by beam
- Light Field Obstruction
- Weight of the Board
- Ease of Use
- Patient Comfort
What is available?
Styrofoam Board with Cutout

- A simple and inexpensive approach
Styrofoam with Memory Foam

- Styrofoam board with cutout and memory-foam overlay, for comfort

*Source: Kirby, A Randomized Trial of Supine versus Prone Breast Radiotherapy (SuPr study): Comparing Set-up Errors and Respiratory Motion. Radiother Oncol 2010
Commerically Available Products

- Arms grab end of platform
- “Massage table” head position
- Be Cautious of Mandible Interception
Commercially Available Products

- Curved Bed opening of 20 or 24 cm
- 3cm “shims” available to raise the height of the board
- Wedging
- Handle
Commercially Available Products

- Ankle Wedge for comfort
- Upper Body thermoplastic immobilization
Commercially Available Products

- Distance between layers: 17 to 20 cm
- 28 lbs
- Carbon fiber
- Foam padding with vinyl coating
Commercially Available Products

- Extension of the couch, not lying on top of couch
- Nothing to intercept beam or light field
Patient Setup
Patient Setup

- Breast tangents
  - Head is turned toward the targeted breast
  - Provides a tripod effect for a stable configuration
  - Minimizes rotation and patient tilt into the breast board opening
Patient Setup

- **Fiducial Markers**
  - Triangulation marks placed on patient’s back
  - BB placed on lateral side of breast, on plane of the triangulation points
  - Medial wire and scar wire placed for field guidance
Patient Setup

- Isocenter
  - Isocenter, for field set up, is placed ~1.5 cm from the medial side of the breast at plane of lateral bb
  - Isocenter is “tethered” to the lateral bb and found with a lateral SSD
Potential Shortcomings

- Reproducibility of a patient’s position is vital for proper delivery of treatment plans.
- Indexing to the treatment table, coupled with a tolerance limit for adjustments are often used as a surrogate for a patient’s position, to help prevent large discrepancies in treatment setup.
- The reliability of this property is contingent upon the patient lying properly on the immobilization device.
Potential Shortcomings

- Although triangulation points are made to be effective in reproducing rotation and location, varied placement on the breast board itself may lead to varying deformation of the breast due to variability in the breast extending through the opening.
- Tethering the isocenter to the lateral bb will allow for the fields to be set up appropriately, but the efficacy of separation-specific treatment planning, with varied distributions throughout the treatment fields, will fall short of accomplishing the goals of the treatment plan.
Investigation in Setup Reproducibility

- NYU offers two internal treatment protocols, NYU 09-0030 and NYU S12-01299, which treat patients with a hypo-fractionated schedule over a span of three weeks, comparing a daily tumor bed boost to a weekly boost.
- Patients under the weekly boost arm have weekly Cone-Beam CT (CBCT) images captured throughout treatment.
Investigation in Setup Reproducibility

- Using this data, we evaluated the variability in setup over a patient’s treatment course.
- We gathered the data for 20 consecutive prone breast cancer patients under the weekly boost arm.
- As per protocol, each of these patients had CBCT images captured once a week, over a treatment span of 3 weeks.
- We investigated several factors
1. **Consistency of a patient’s rotation on the breast board was examined.**

   - Using the Sternal Angle and the Xiphisternal Junction as markers, a point midway was used to represent a consistent plane for measurement.
   - Rotation of the patient’s sternum relative to the flat plane of the breast board was used for comparison.
Investigation in Setup Reproducibility

2. Volume Consistency was investigated

- Three-Dimensional assessment of the breast tissue, within a certain area, was performed by contouring within the following constraints:
  - The Sternal Angle and the Xiphisternal Junction were used as sup/inf markers
  - The medial edge of the sternum and edge of the latissmus dorsi as left/right markers
  - The Chestwall and Skin surface were used as ant/post markers
Investigation in Setup Reproducibility

3. Displacement Measurement

- These volumes were then used as a subject for patient to breast board setup variation comparisons.
- Displacement of the center of the three-dimensional volumes were measured relative to a reference point on the opening of the breast board.
- The reference point used was the point on a parallel, tangent to the opening of the breast board in a coronal view.
- This comparison was performed between the simulation CT and the CBCT images to measure weekly variability.
Investigation in Setup Reproducibility

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</tr>
</tbody>
</table>
Investigation in Setup Reproducibility

What did we find?

- Measured displacement differences between each CBCT image and the Simulation CT for each dimension, accounting for direction (+/-).
- Given there were few data points for each patient, the mean displacement values for each CBCT and each dimension were gathered.
- The absolute difference values were then averaged to arrive at these single values (cm).

<table>
<thead>
<tr>
<th>Mean of 3D deviation</th>
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<td>Mean X deviation</td>
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<td>Mean Y deviation</td>
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<tr>
<td>Mean Z deviation</td>
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</table>
Investigation in Setup Reproducibility

What does this mean?

- With the exception of the X dimension (L/R), we are setting up our patients with fair reliability, compared to our treatment plan/simulation CT, at <8 mm.

- The X dimension may not play as crucial a factor in this setup as the isocenter is tethered to the lateral bb, and the laterality of the isocenter is dependent on an SSD reading, adding assurance to its placement, relative to the breast surface, in the X dimension.

<table>
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<tr>
<td>Mean Z deviation</td>
<td>0.74</td>
</tr>
</tbody>
</table>
Investigation in Setup Reproducibility

However, although the isocenter placement may be reliably performed, the deformation of the breast may vary dependent on the L/R placement of the patient on the breast board.

Simulation CT versus Week 1 CBCT
Potential Solution for Reproducibility

So what do we do?

- We need to reliably set up our patient’s on the breast board, which is then indexed to the treatment couch.
- Indexing all three dimensions may help in these setups.
- By doing this, after the patient has been setup, the lateral SSD should be used as a verifier of setup, rather than the driving force.
Revisit Patient Setup

- Fiducial Markers
  - Posterior triangulation mark placed at couch lateral 0.0 cm
  - Isocenter placed at R/L plane of posterior BB
  - All couch parameters entered into R and V system prior to day 1
Investigation in Setup Reproducibility

- This setup was used beginning in the summer of 2013.
- We gathered data for 20 more consecutive prone breast cancer patients under the weekly boost arm.
- Each of these patients, under the same protocols, had CBCT images captured once a week, over a treatment span of 3 weeks.
- We investigated the same factors:
  - Consistency of patient rotation
  - Volume Consistency
  - Displacement Measurement
Investigation in Setup Reproducibility

<table>
<thead>
<tr>
<th></th>
<th>Sim CT</th>
<th>CBCT1</th>
<th>CBCT2</th>
<th>CBCT3</th>
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<tr>
<td>Mean X deviation</td>
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<td>Mean Y deviation</td>
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<tr>
<td>Mean Z deviation</td>
<td>0.70</td>
</tr>
</tbody>
</table>
Investigation in Setup Reproducibility

What does this mean?

- There was little change in the Y (ant/post) and Z values (sup/inf). However, we found a significant change in the X dimension (L/R).
- As expected, we were able to tighten variability on all three dimensions, with good reliability, at <8mm.
- This gives us assurance that patients are setting up properly, as per CT simulation. Thus increasing the likelihood our treatment plans are being delivered safely, as intended.
Consistency of a patient’s rotation on the breast board was examined using sternal rotation for comparison between the CBCTs to the simulation CT images.

All values were gathered and variability was examined based on setup type.
Freq distribution of sternum angle offsets as measured on CBCT

change in patient sternum angle CT-CBCT (degrees)
Patient Rotation

What did we find?

- Median sternum rotation on the breast board at simulation was 6.4°
- Rotation variation during a course of treatment is small
- ~2.7° one standard deviation
What did we learn?

- We can effectively position patients on the breast board with ~7mm variance.
- Rotation variation during a course of treatment is small.
- Feedback from our therapists tell us that our patients can tolerate treatments well and that setup is reproducible.
What did we learn?

- A quality assessment analysis helped to improve treatment reliability and patient safety in our clinic.
- It provided assurances regarding patient setup reliability.
- We may be able to tighten our tolerances due to our results.