I. INTRODUCTION

- Over 40,000 women will die from breast cancer (BC) in the United States in 2017.
- Radiotherapy (RT) is a critical component of breast cancer management, yielding a substantial survival benefit but can result in inadvertent exposure of large volumes of normal tissues to low and moderate doses of radiation.
- There is a 7% increase in relative risk (RR) of cardiac disease with each 1-Gy increase in mean heart dose, or 35% total for the typical patient.
- Left-sided BC patients who receive RT to the chest wall have a 4-fold higher risk of cardiac events than patients with right-sided BC.
- Because cardiac injury is known risk of treatment, early markers of heart injury could be beneficial for follow-up management in these patients and may help identify new techniques that would improve the therapeutic ratio of treatment.

II. METHODOLOGY: IMAGING AND PREPROCESSING

IMAGE ACQUISITION

- Images were acquired at 8-10 time points over the systolic phase of the cardiac cycle with parallel-tagging cardiac MR images, in patients with left-sided breast cancer under protocol UPITF 1419 IRB.2071. - Images were acquired before and 6-12 months after completion of RT.

HEART LEFT VENTRICLE CONTOUR SEGMENTATION

- An in-house semi-automatic snake based contouring toolkit was used to segment the Left Ventricle (LV) endocardial and epicardial borders on each image slice and time frame. Mathematical models for each surface (Fig. 3) were defined in a prolate spheroidal coordinate system (PSCS) (Eqs. 1) with α, the radial coordinate, expressed as a series expansion in 8 and μ, the circumferential and longitudinal angles.

\[
\frac{d^2u}{ds^2} + \frac{1}{
\begin{align*}
\sin^2(s) + \cos^2(s) = 1 \\
\end{align*}
\]

DEFORMABLE IMAGE REGISTRATION

- The deformation of the heart LV was defined by modes of deformation in the local PSCS, followed by 3 rotations and 3 translations in x, y, and z.
- These modes and motions were applied to de-warpage of the LV in the follow-up frame back to the reference time when the tags were generated. Virtual tagged images were deformed according to the model and compared with the patient MR images to determine the modes.

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III. CONCLUSIONS & DISCUSSION

- We have developed methods to gather and analyze pre- and post-treatment MR images, with tags, in breast cancer patients.
- The results permit regional assessment of sub-clinical changes in heart wall strain, and compare these metrics with regional radiation dose.
- Tools have been developed to visualize and quantify 3D changes in heart wall function, with correlation with radiation exposure, and perform statistical analysis of the outcomes.
- These analysis techniques are hoped to enable us to address key clinical questions:
  - Does proton therapy improve the therapeutic ratio of breast cancer radiation treatment by reducing the severity of radiation toxicity to the heart?
  - How can we identify breast cancer survivors that are at an elevated risk for cardiac disease who may benefit from proton therapy or altered RT?
  - Is there a role for cardiac imaging in routine clinical follow-up care of breast cancer patients for identification of sub-clinical cardiac toxicity?

IV. REFERENCES

5. O'Dell WG, Siva Kumar S. Determining prosal phsysiologic mode of cardiac deformation directly from tagged heart images. 25th ISMRM Scientific Meeting and Exhibition; Honolulu, Hawaii, (WAM2007) April 2007