Evaluating Variability in the Measurement of Global Longitudinal Strain with Slice Orientation

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I. INTRODUCTION

- There are many clinical scenarios in which early detection of changes in the heart's functionality can be critical in determining whether to maintain or modify a patient's treatment plan.
- Changes in the heart's functionality is conventionally measured using Left Ventricular Ejection Fraction (LVEF), which when using limited views and common geometric assumptions could yield an error as high as 49%[1].
- A new metric coined Global Longitudinal Strain (GLS) is supposedly more sensitive than conventional LVEF methods[2].
- The GLS scale is manufactured, meaning the normal value for GLS was identified by computing the value for multiple healthy patients[3]. Therefore, the value does not correlate with a concrete measure of the heart.
- The goal of this project is to conduct a rigorous analysis of the limitations associated with GLS with regards to selection of the long-axis slice orientation.

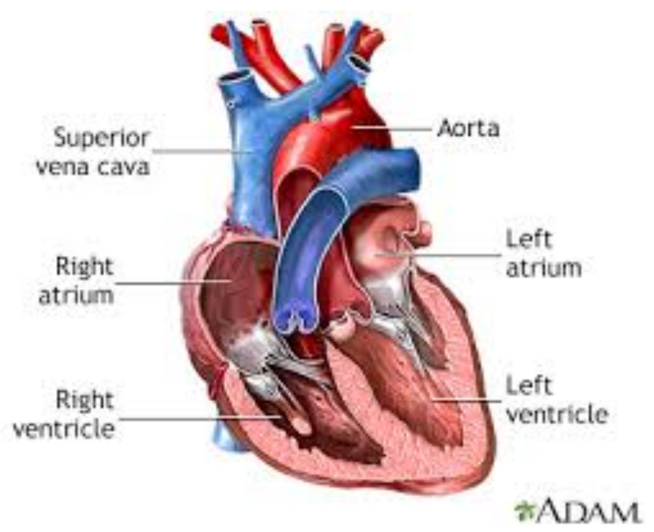

Figure 1 . A diagram of the heart. The measurements taken for GLS all correlate to values derived from the left ventricle of the patients heart. Between the left atrium and the left ventricle is the mitral valve. GLS values are derived using the arc length between the mitral valve and the apex of the left ventricle.

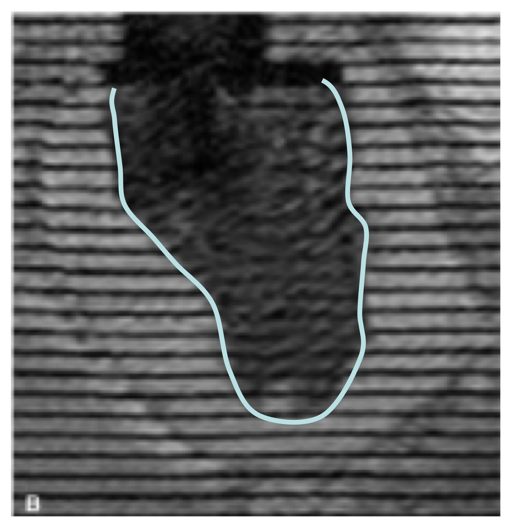

Figure 2 . Inner contour of the left ventricle during systole on an MRI scan. Points are plotted along the inner contour of the left ventricle as shown in Figure 2. Different perceptions of the inner contour can result in different arcs being drawn.

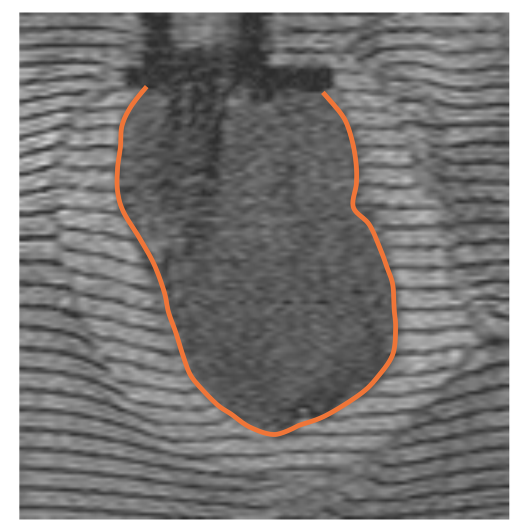

Figure 3 . Inner contour of the left ventricle during diastole on an MRI scan. Points are plotted along the inner contour of the left ventricle as shown in Figure 3. The arc drawn is Figure 3 is comparatively larger than the one in Figure 2.

STUDY HYPOTHESES : Each of the twelve long axis slice orientations taken from different Magnetic Resolution Image (MRI) viewing angles will yield different GLS values, indicating a large interpatient variability in the GLS value.

II. METHODOLOGY

IMAGE ACQUISITION

High resolution magnetic resonance imaging (MRI) scans were acquired of an isolated canine heart undergoing passive inflation. Twelve long-axis views were prescribed radially about the left ventricle central axis. In each view, points were placed along the inner contour of the left ventricle to create an arc from the mitral valve to the apex of the left ventricle and then back up. The percent difference in the arc length from systole and diastole was calculated to produce a GLS estimate for each view.

GLOBAL LONGITUDINAL STRAIN COMPUTATION

A program coded in-house using snake-based segmentation program, an active contour that minimizes bending energy, was used to gather geometric information about the location of the plotted points along the left ventricle's inner contour. The coordinates of the various points plotted along the arc where provided from both the diastole and systole. The distance between each point was calculated and totaled to find the arc length for each phase of the heart.

$$\text{Global Longitudinal Strain (GLS)} = \frac{\text{LV Diastolic Arc Length} - \text{LV Systolic Arc Length}}{\text{LV Diastolic Arc Length}} * 100 \qquad \textbf{Eqn. 1}$$

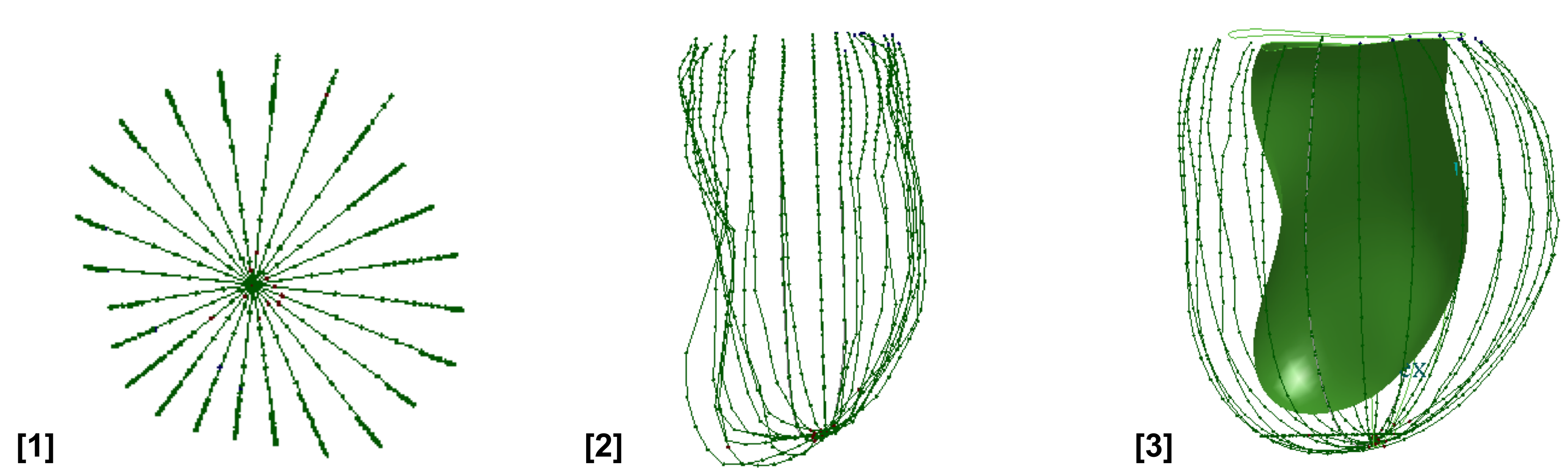

Figure 4 . The various long axis slice orientations considered.[1] shows the top view, and [2] shows the side view of the twelve view slices taken at varying angles. Angles from 0 to 165 degrees, taken 15 degrees apart, each had a GLS valued computed to show that each angle would produce a different value, hence showing the intra-variability of this measurement. [3] shows the inside of the left ventricle in the solid green enveloped in the thick surrounding cardiac tissue.

ACKNOWLEDGEMENTS

Funding for this work is from the UF Emerging Scholars Program and the Department of Radiation Oncology at UFHCC.

III. RESULTS

VARIABILITY AMONG ALL POSSIBLE IMAGE ANGLES

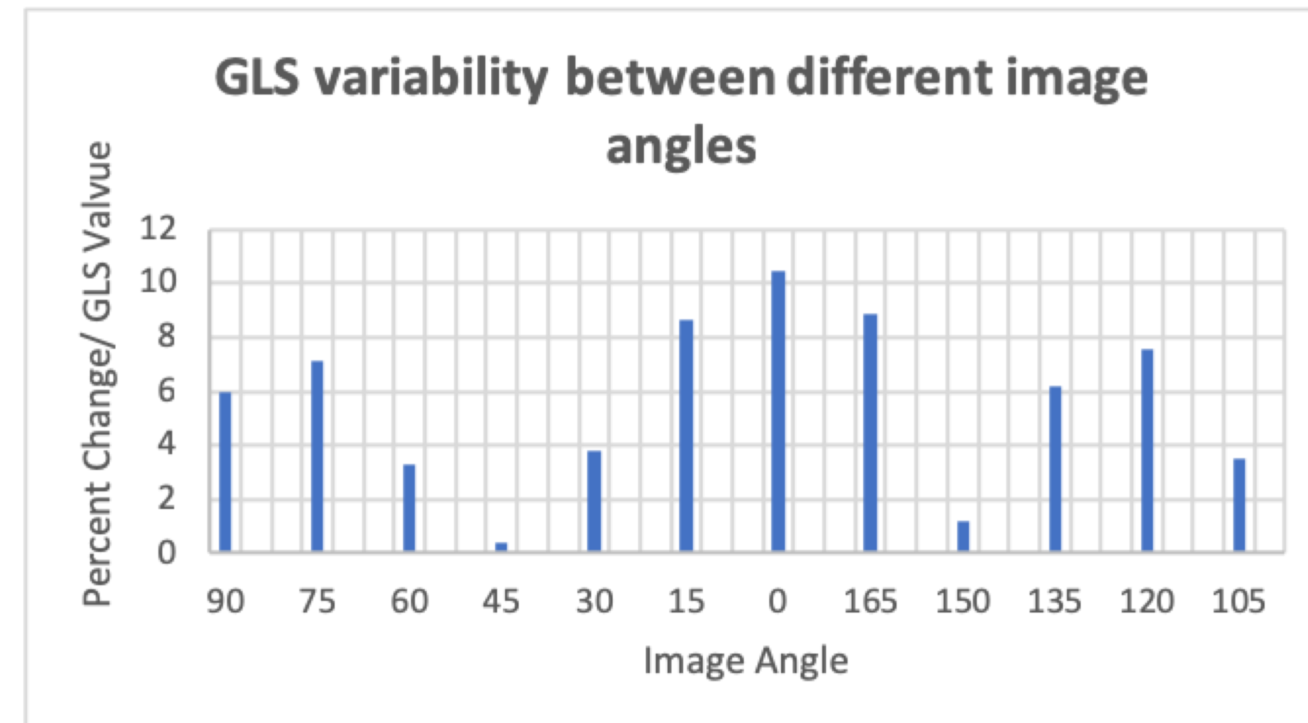

Figure 5 . Plot of GLS values calculated from each image angle.
The graph displays the various and widely varied GLS values that were all generated for the same heart, but with different angles of slice orientation. A pattern in the graph can be seen through the curvature of the graph. Angles such as 45 and 150 produced the smallest GLS values. Angles such as 75, 0, and 120 produced the largest GLS values. Healthy human patients reportedly have a GLS value close to 20. The range of values from the dog heart only goes from 0.4 to 10.5. The lower than expected range may be the result of using a canine heart instead of an adult human heart.

VARIABILITY ASSOCIATED WITH THE COMMONLY USED FOUR CHAMBER VIEW

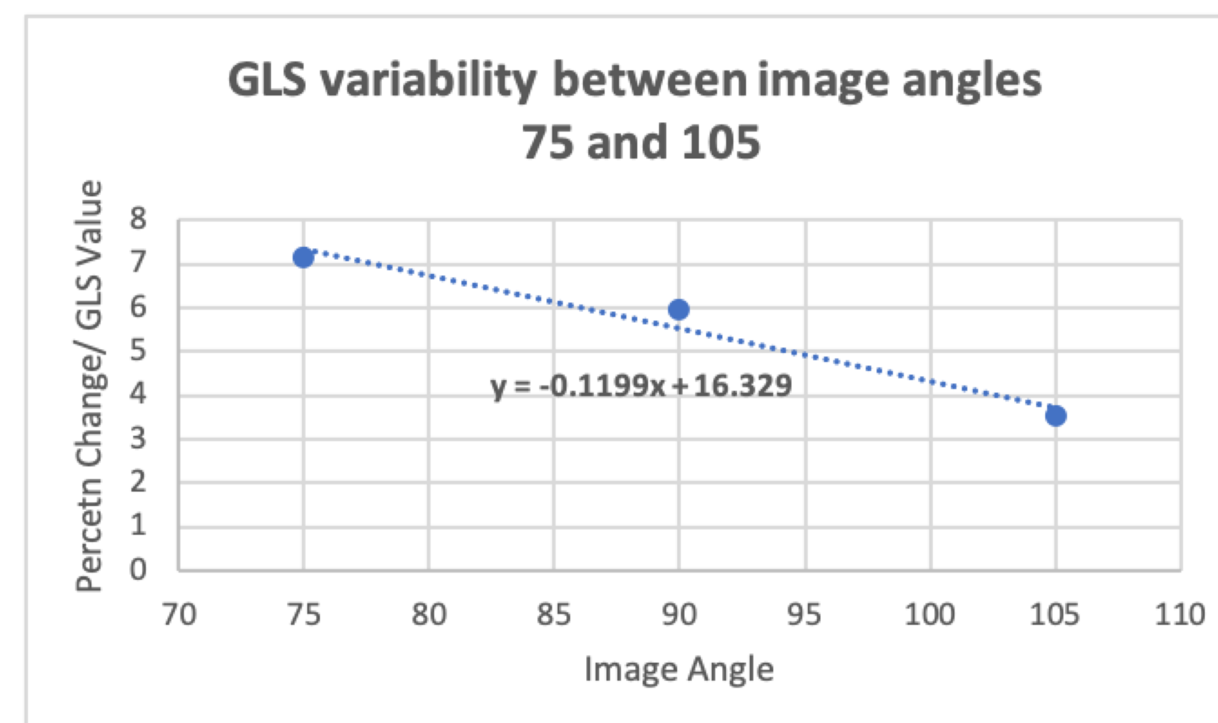

Figure 6. Plot of GLS values for angles 75, 90 and 105 numerically aligned.
Many physicians will use the four chamber view, the slice of the heart that shows all four chambers of the heart, to calculate GLS. The four chamber view correlates to the 90 degree angle in our data. By aligning the values from 75 to 105, the closest slice on each end of the 90 degree slice, the line of best fit can be drawn. The slope of this line shows how much the GLS value will differ with each varying degree from 90. Percent difference can be calculated by dividing the slope by the 90 degree GLS value, 5.945, and multiplying it by 100. this calculation shows that a with each angle deviation from 90 an uncertainty of 2 percent is added to the calculated GLS value.

STATISTICAL ANALYSIS

The GLS values ranged from 0.42 to 10.42 over the 12 views. The average GLS value was 5.59 with standard deviation of 3.15 (or 56%). In clinical settings, it is common to use an MRI scan of the four-chamber view (capturing both atria and ventricles) which correlates in our experimental setup to the 90-degree slice. The slope for the line of best fit for GLS over the range 75 to 105 degrees was 0.12, meaning that for every degree away from 90 an error of 2% is added.

III. DISCUSSION & CONCLUSIONS

- There is a large inter- and intra-patient variability in GLS depending on which angle is chosen for the viewing perspective.
- Determining the inner contour of the left ventricle is based upon human interpretation of grayscale edge pixels, as different individuals may produce different arc length values for the same MRI scans.
- In clinical settings only one viewing perspective is used to compare two time points. As the heart contracts, it shifts and rotates 1-2 centimeters, so even if the initial slice was aligned with the true apex of the left ventricle for the first image, the viewing perspective is no longer aligned with the initial cardiac tissue for the second image.
- With every degree deviation from 90, which is correlated with the commonly used four chamber view, a 2 percent uncertainty in GLS is added.
- Going forward, this project can attempt to correlate GLS values with a concrete cardiac metric or focus on designing a metric that can produce a more accurate measure of cardiac function.
- Finding accurate ways to measure changes in heart functionality is important in analyzing the effectiveness of treatments such as radiation therapy.

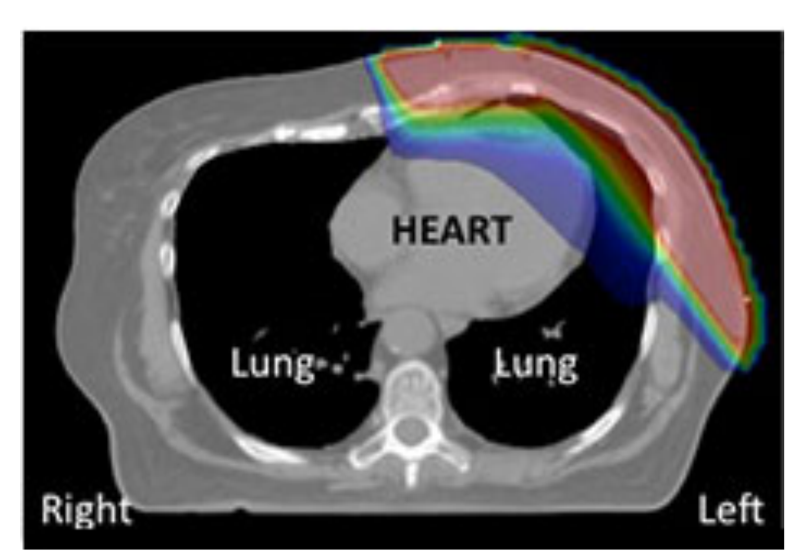

Figure 7 . The exposure of the heart to radiation therapy in a breast cancer patient. Research on the effectiveness of radiation therapy in treating breast cancer can use a measurement like GLS to quantity the collateral damage done on the heart during the treatment. In Figure 7, the blue coloration on the heart shows that the organ is exposed to radiation during the treatment, which can degrade cardiac tissue.

IV. REFERENCES

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