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Project 2

BME 7450

Submitted by,
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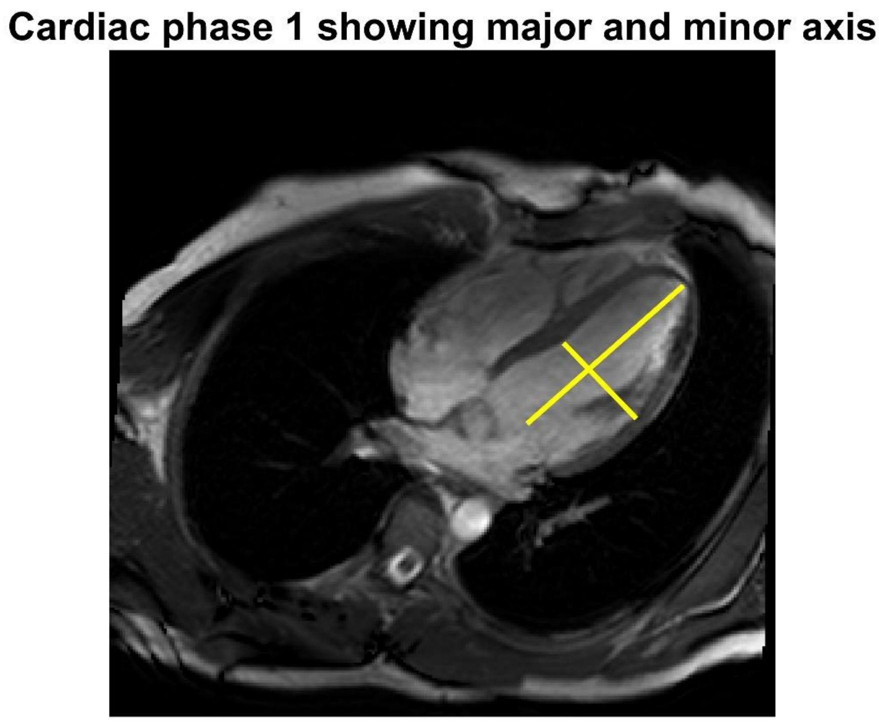
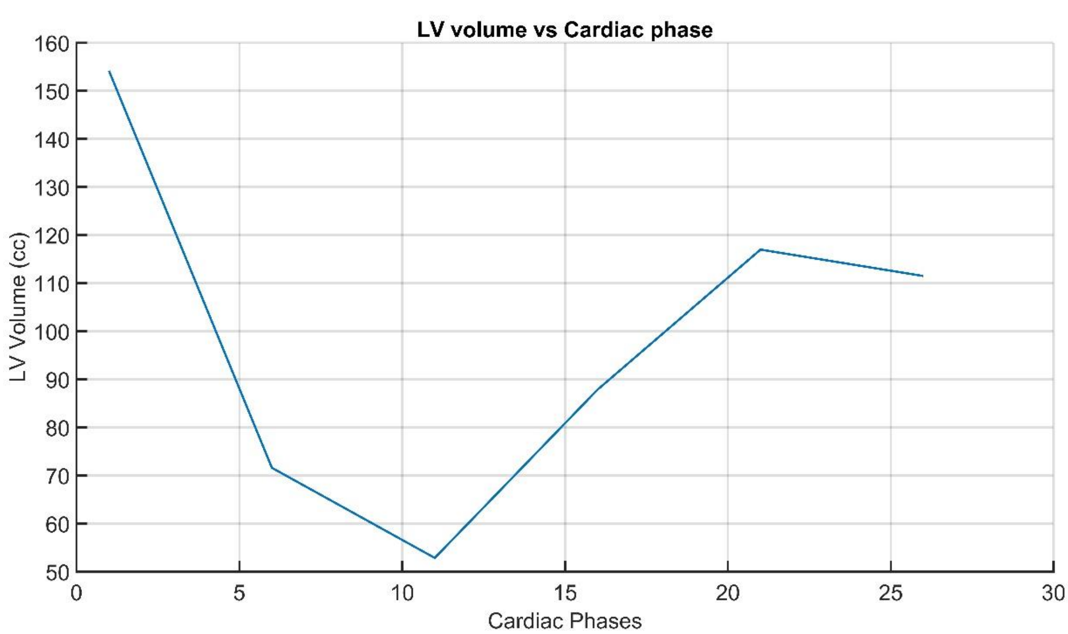
- **The image for the first cardiac phase with the major and minor axes shown.**



- **Plot of LV volume versus cardiac phase**



Questions

1. *<u>What is the diastolic (i.e., maximum) volume of the LV?</u>*
   Answer:
   The diastolic volume of LV is 154.1322 cc.

2. *<u>What is the systolic (i.e., minimum) volume?</u>*
   Answer:
   The diastolic volume of LV is 52.8530 cc.

3. *<u>What is the ejection fraction?</u>*
   Answer:
   Ejection Fraction = $\frac{diastolic\ colume - systolic\ volume}{diastolic\ volume}$
   $= \frac{154.1322 - 52.8530}{154.1322}$
   = 0.657

4. *<u>Could you use the same approach to estimate the volume of blood ejected from the right ventricle? If not, explain why. Do you expect the right and left ventricular ejection volumes to be equal?</u>*
   Answer:
   I don't think that we can use the same approach for right ventricle (RV) because although left ventricle (LV) is more or less like an ellipse in its cross section, RV is not of any kind of regular shape. So, we cannot use the volume formula we have used here for LV.

   I expect the ejection volumes to be less for RV than LV because,
   - the wall of RV is much thinner compared to the LV, and so, it cannot generate as much pressure as the LV. Hence, it can push less amount of blood out of the chamber.
   - Also, RV has to send blood to lung only which is pretty close to heart. On the other hand, LV supplies blood to all the distant body parts. So, LV needs to generate more pressure than RV which also causes LV to eject more blood than RV.

5. *<u>We assumed that the two minor axes, b and c, are equal, but this is only approximately true. Let b be the measured minor axis and c be the unmeasured minor axis (i.e., the minor axis in the direction perpendicular to the image plane). Suppose that in a group of patients c=b on average, but there is a 20% variation in the ratio, i.e., the standard deviation of c/b in this group is</u>*
   $$\sigma\left(\frac{c}{b}\right) = \frac{\sigma(c)}{b} = \frac{\sigma(b)}{c} = 0.2$$
   <u>Assuming this is the most important source of errors, use a 'propagation of errors' approach to predict the errors in ventricular volume estimates for this population. Express your answer as the fractional error in ventricular volume, $\frac{\sigma(V)}{V}$.</u>

Answer:
From error propagation formula, we have,

$$\sigma(V) = \sigma(c) * \frac{dV}{dc}$$
$$= \sigma(c) * \frac{4\pi}{3} * \frac{a*b}{8}$$
$$= \sigma(c) * \frac{V}{c}$$

$$So, \frac{\sigma(V)}{V} = \frac{\sigma(c)}{c}$$
$$= \frac{\sigma(c)}{b} \text{ [because b=c]}$$
$$= 0.2$$

So, the fractional error in calculating ventricular volume would be around 20%.

6. *<u>Besides the possibility that c not equal b, what are the most important limitations to the accuracy of your measurement of ejection fraction? What changes to the experiment might improve the accuracy?</u>*
Answer:
The main limitations are, in my opinion,
   - We are selected the points for major and minor axis just by eyeballing and assumptions which are not accurate. The resolution of the image was also very poor making it difficult to select the points. In addition, the major and minor axis should be perpendicular to each other and should meet each other at their middle point. But since we are doing it via hand and eye, this criterion might be violated.
   - We considered the LV an ellipse while calculating its volume. But in reality, LV is not a perfect ellipse. Its shape is not regular.

To improve the accuracy of the experiment, we need to find a more accurate method to calculate volume. If we can have a 3D image of the heart during diastolic and systolic phase, we can have more realistic measure of the volume. Also, more sharper image always helps in selecting the major and minor axes.

7. *<u>What medical conditions (i.e., diseases or cardiac abnormalities) do you think this technique could be used to diagnose or assess?</u>*
Answer:
In cardiac abnormalities where ejection fraction goes below the normal level (50-75%), this ejection fraction can be an index/ measure to diagnose those conditions. Such conditions include heart failure/cardiomyopathy, heart attack/myocardial infarction, valve diseases, etc.

- **Matlab Script:**

```
load('proj2Data')

%Makes a movie:
figure
nFrames = 30;
for index = 1:nFrames
    imagesc(squeeze(image_3d(:, :, index)))
    %Setting the intensity scale based on the first image:
    if (index == 1)
        cLim_v = get(gca, 'CLim');
    else
        set(gca, 'CLim', cLim_v)
    end
    axis image
    axis off
    colormap(gray)
    title(['Cardiac phase: ', num2str(index)])
    drawnow
    mov(index) = getframe;
end
fps = 8; % frames per second.
nReps = 4; % number of repetitions.
movie(mov, nReps, fps)

% Defines the major and minor axes of the ellipse in each frame:
skip = 5; % Number of phases to skip.
nVols = length(1:skip:nFrames);
volume_v = zeros(1, nVols);
for index = 1:skip:nFrames
    imagesc(squeeze(image_3d(:, :, index)))
    set(gca, 'CLim', cLim_v)
    axis image
    axis off
    colormap(gray)
    hold on

    % Get axes:
    title(['Cardiac phase ', num2str(index), ' define major
axis'])
    % Measures the major axis:
    [x_mj, y_mj] = ginput(2);
    row_mj = round(y_mj);
    col_mj = round(x_mj);
    d_mj = sqrt((row_mj(1)-row_mj(2))^2+(col_mj(1)-col_mj(2))^2);
```

```
    title(['Cardiac phase ', num2str(index), ' define minor
axis'])
    % Measures the minor axis:
    [x_mn, y_mn] = ginput(2);
    row_mn = round(y_mn);
    col_mn = round(x_mn);
    d_mn = sqrt((row_mn(1)-row_mn(2))^2+(col_mn(1)-col_mn(2))^2);
    volIndex = (index-1)/skip + 1;
    % Calculates the LV volume:
    volume_v(volIndex) = (4*pi*d_mj*dx*d_mn*dx*d_mn*dx)/(3*8);
end

%calculates the ejection fraction
ejection_fraction = (max(volume_v)- min(volume_v))/max(volume_v);
```