Chapter 8

Left ventricular diastolic dysfunction and left ventricular hypertrophy

8.1 Left ventricular dysfunction

The left ventricular dysfunction is often the root cause of many sub clinical and clinical cardiac complications. It causes to develop compensatory mechanisms that cause structural and functional changes in the heart. In the presence of persisting ischemia, the myocardium undergoes changes resulting in thinning of the wall, alterations in wall stress and contractility and spherical remodeling from an original elliptical contour. Changes in contractility may affect concentric, longitudinal and also in the oblique/ rotational axis, constituting left ventricular systolic dysfunction. Anatomic changes in chamber volumes due to aging, degeneration and disease may alter mitral valve flexibility and change the rates of LV filling in early and late diastole and may reflexely increase atrial pressures thereby affecting LV filling pressure. Such changes contribute to LV diastolic dysfunction and may be associated with apparently normal systolic function. This causes further complications as reduced mechanical efficiency and worsens the congestive heart failure.[70] Also left ventricular dysfunction causes reflex activations of neuro hormonal axis further affecting the autonomous nervous system. The specific, safe, quick and noninvasive diagnostic technique is the echocardiogram. The algorithm of diagnosing Left ventricular diastolic dysfunction by echocardiogram is as follows-

Step 1
If subject suffers from progressive dyspnea (breathlessness) and / nocturnal or decubitus dyspnea (breathlessness when lying down in lateral position).

Step 2
Check for evidence of effective left ventricular systolic function (Ejection fraction greater than 50%)

Step 3
Check for evidence of LV diastolic dysfunction by evaluating Mitral diastolic early/ late pressures and for evidence of raised LV filling pressure by Tissue Doppler at the Mitral annulus. (E/E’ is the ratio of maximal values of passive mitral inflow velocity to medial / lateral early mitral diastolic velocity indicating various grades of diastolic dysfunction).

Step 4
Check if PA pressure is raised. If PA systolic pressure greater than 10 mmHg or RVSP > 40 mmHg by TR jet method. The figure 8.1 shows the variation of A/E and E/E’ in different stages left ventricular diastolic dysfunction.

![Figure 8.1 - shows the variation of A/E and E/E’ in normal and different stages left ventricular diastolic dysfunction. Figure adapted from [70]](image)

### 8.2 Poincare plot analysis.

The HRV test can diagnose the LVDD at preclinical stage. HRV analysis using Poincare technique is used in the diagnosis of LVDD. This method of computing heart rate variability is a noninvasive and safe technique that takes into consideration the nonlinearity of ECG signal and hence is more accurate than the prevailing methods used in time and frequency domain techniques. [63]

The Poincare plot is a plot of RRi versus RRi+1 for all i∈N-1 where data set of N RR intervals is considered. The Poincare plot is a visual tool and uses the ratio between standard descriptors for short term correlation (SD1) and long term correlation (SD2) between RR intervals to assess the health of the heart. It has been found that the peculiar shape of RR interval is not an artifact or mere placement of point but a specific temporal correlation between the successive RR intervals and hence prelates closely to the natural rhythm of heart as a response to many different complex closed loop systems controlling the heart. [71] The shape of the RR interval distribution shows an elliptical pattern and the ratio of SD1/SD2 should be higher for a healthy person. The shape of RR interval distribution is non-elliptical pattern and ratio is much lower for a subject with impaired heart or reduced HRV. The typical cases of normal and impaired subject are as shown in the right panels of the figure-8.2. Their corresponding HR variations are also shown in the left panel of the figure.
Figure 8.2 shows the variation of heart rate variation of normal and impaired heart and the corresponding Poincare plot. Figure adapted from [71]

8.3 Modified Poincare Plot Analysis Used In Proposed Method.
Further division of SD1 into two new descriptors SD1_up and SD1_down that represent decelerations and accelerations of RR interval respectively. The line of $\pi/4$ slope i.e. y=x line in the Poincare plot represents the equal consecutive RR intervals. The RR interval points with increased heart rate are represented below the line and The RR interval points with decreased heart rate are represented above the line. There is a typical asymmetry found in all Poincare plots. This asymmetry finds correlation that can be explained physiologically that the parasympathetic power spectral densities are higher than the sympathetic power spectral densities [63].

8.3.1 Algorithm Of Modified Poincare Plot Analysis.

1. Acquire the ECG samples of different groups.
2. Compute the RR intervals and store it in a file.
3. Compute the average RR interval.
4. Compute the deviation from the average value for all the RR interval values.

5. If the corresponding RR interval is greater than average the resulting value is negative. Store it in array1.

6. Else if the value is positive, store it in array2.

7. Compute the average of the two arrays. The average of first array is the SD1_up and the average of the second array is SD1_down.

8. Compute the ratio of the two for all the datasets of the ECG acquired.

**8.3.2 Results**

Table 8.1 shows the results of the average value of the ratio of sympathetic power to parasympathetic power, standard deviation and the number of subjects in each cohort. Table 8.2 shows the p-value for the t-test for two tailed unequal variance. The p-value in all cases are less than the critical value shows that the ratio values within the groups are statistically independent.

Table 8.1 – Table average value of the ratio of sympathetic power to parasympathetic power, standard deviation and the number of subjects in each cohort.

<table>
<thead>
<tr>
<th></th>
<th>Number of subjects</th>
<th>Average Ratio of sympathetic power to parasympathetic power</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>21</td>
<td>1.192386</td>
<td>0.30068208</td>
</tr>
<tr>
<td>Diabetic</td>
<td>20</td>
<td>0.858</td>
<td>0.22911221</td>
</tr>
<tr>
<td>IHD,INHD</td>
<td>20</td>
<td>0.67426</td>
<td>0.23037031</td>
</tr>
<tr>
<td>D &amp; H</td>
<td>19</td>
<td>0.825859</td>
<td>0.10643245</td>
</tr>
<tr>
<td>Hypertensive</td>
<td>19</td>
<td>1.226476</td>
<td>0.26869055</td>
</tr>
</tbody>
</table>

Table 8.2 – Table showing results of T-test.

<table>
<thead>
<tr>
<th>Two tailed T-test for unequal variance</th>
<th>P-value</th>
<th>critical value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetic</td>
<td>0.0002</td>
<td>2.026</td>
</tr>
<tr>
<td>IHD,INHD</td>
<td>1.27E-07</td>
<td>2.024</td>
</tr>
<tr>
<td>D &amp; H</td>
<td>7.72E-06</td>
<td>2.059</td>
</tr>
<tr>
<td>Hypertensive</td>
<td>0.689757</td>
<td>2.021</td>
</tr>
</tbody>
</table>


### 8.3.3 Conclusion

In case of modulated autonomous nervous system the ratio is found to be lower. This statement of observation also finds suitable reinforcement from the physiological fact that in case of diabetic subjects rate variability. Hence the SD1\_down index has higher values and the ratio is decreased. The results are correlating with the above stated fact. Also the increase in this ratio correlates with the evidence of LV dysfunction. LV dysfunction is an abnormality that results due to myocardial ischemia/infarction. The ratio is found to be higher in hypertensives because the sympathetic power exceeds the parasympathetic power. In the case of this data set the diabetic and hypertensive cohort shows a lower value of the ratio showing that diabetic conditions are predominant than hypertensive in this cohort.[63]

### 8.4 Complication of Left Ventricular Hypertrophy (LVH)

Left ventricular hypertrophy (LVH) is mal adaptive response and risk factor in chronic pressure overload. Increased myocardium results in diastolic and/or systolic failure, atrial fibrillation and sudden death. [62] [33] As hypertrophic growth is slow and clinically invisible, early diagnosis is essential to control the mortality and morbidity. Study aims at establishing indices for diagnosis of LVH by using safe and non-invasive techniques and to indicate modification in autonomous nervous system in hypertensive subjects.

Renin-angiotensin-aldosterone is the hormone complex that maintains homeostatic condition in body. Angiotensin-I is a vasoconstrictor required to maintain the lumen dimension of arteries. Angiotensin-II that is required to hydrolyze Angiotensin-I is found to have profibrotic effect on myocardium.[33] The Left Ventricular Hypertrophy muscle mass growth can be clearly observed in figure-8.3. The typical ECG can be observed in figure-8.4. Since the ECG signals are highly subjective, they cannot be ECG signal is not confirmatory diagnostic test. The echocardiogram of the normal and left ventricular hypertrophic heart is shown in figure-8.5

![Figure-8.3-Normal and hypertrophic myocardium. Figure adapted from [78]](image1)

![Figure-8.4- ECG showing sharp R-R peaks of LVH subject. Figure adapted from [78]](image2)
Modified Poincare plot method as explained in section 8.3 and it’s algorithm is used in separating the sympathetic and parasympathetic power. Table 8.3 shows the details. Table 8.4 shows that there is no dependency between sympathetic and parasympathetic power values between the hypertensive subjects with and without LVH.

Table 8.3-Table for HRV indices

<table>
<thead>
<tr>
<th>Category type</th>
<th>Average Heart Rate (From FDM tools)</th>
<th>Average HRV (SDNN) (From TDM tools)</th>
<th>Average Sympathetic Power (From Poincare tools)</th>
<th>Average Parasympathetic Power (From Poincare tools)</th>
<th>Average Total Power (From Poincare tools)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control group (26 subjects)</td>
<td>63.8428 (+/- 2.92)</td>
<td>45.72 (+/-13.41)</td>
<td>111.19 (+/-33.45)</td>
<td>93.48 (+/-22.74)</td>
<td>206 (+/-52.39)</td>
</tr>
<tr>
<td>Hypertensive subjects (25 subjects)</td>
<td>68.9475 (+/- 7.63)</td>
<td>45.43 (+/-18.03)</td>
<td>130.07 (+/-41.20)</td>
<td>123.00 (+/-46.83)</td>
<td>244.89 (+/-71.32)</td>
</tr>
<tr>
<td>Hypertensive subjects Suffering from LVH</td>
<td>69.8848 (+/- 8.29)</td>
<td>52.254 (+/-17.28)</td>
<td>155.40 (+/-57.93)</td>
<td>124.64 (+/-36.87)</td>
<td>262 (+/-102.91)</td>
</tr>
</tbody>
</table>

Table 8.4 T-test indicating the independency of data between the groups.
The list of observations that are deduced from the results and their physiological analogy can be stated as below.

It has been observed from the results shown in table-8.3 that the average heart rate is in decreasing order of hypertensive and hypertrophic subject, hypertensive subject and control group. The findings are consistent with the physiology since the hypertensive and hypertrophic heart has to pump at a faster rate to fulfill the demand of blood against the elevated systolic pressure that restricts the blood flow. It has been observed from table-9.3 that heart rate variability is found to be in the decreasing order hypertensive and hypertrophic subjects, hypertensive subjects and the control group. This is due to the pharmacological intervention for treatment of hypertension and/or LVH. It has been recorded in literature that SDNN on average has no effect in case of LVH subjects. It has been also been recorded that SDNN is found increased during morning and night for LVH subjects. The ECG data samples were collected in the morning from 9.00 a.m. to 11.30 a.m. It has been found that from the results shown in table-8.4, that total average electrical power of is in decreasing order in hypertensive and hypertrophic subject, hypertensive subjects and control group. This is consistent with the physiology that the electrical power of hypertensive and hypertrophic heart is more to work against the constricted artery lumen and reduced ventricular filling due to elevated systolic pressure or mitral regurgitation or to compensate an infracted myocardium as the case may be. In comparison hypertensive heart has to overcome the constricted artery lumen only.

The sympathetic power is in the decreasing order in case of hypertensive and hypertrophic subjects, hypertensive subjects and control group. This observation shown in table-9.3 finds analogy with the physiological condition that in case of hypertensive subject, heart rate is found to be higher to supply the inadequacy of blood supply. Hence sympathetic power also increases as a compensatory mechanism. [78]

Thus it can be concluded that a novel, safe, noninvasive, deployable, cost effective diagnostic tool has been developed that can diagnose LVDD and LVH at preclinical stage and can be conducted by paramedical staff.