Morphometric Analysis of Annulo-Papillary Distances in Left Ventricle of Human Hearts

S.Kavitha¹*, V.Selvam²*, A.Anand¹**, K.Y.Manjunath³**

¹Assistant Professor, ²Professor,
¹²Department of Anatomy, ³Department of Forensic Medicine, Vinayaka Missions Kirupananda Variyar Medical College, Salem.

Corresponding Author: S.Kavitha

ABSTRACT

Objective: Heart dimensions play an important role in heart valve replacement surgeries of the modern era. While fixing of valve during replacement even a minimal difference in the measurements will be crucial for effective postsurgical effective functioning of the valve. There is a marginal difference in the measurements between the attachments of the chordae from the papillary muscle to the valve and the measurements between the papillary muscles to the valve. This study aims to highlight the crucial differences between these measurements which will provide a ready reference for the operating surgeon.

Materials & Methods: The left ventricle was studied in 50 human hearts. The distances between the anterior and posterior papillary muscles to the mitral annulus were measured from four fixed points.

Results: The mean vertical diameter of the mitral annulus was 16.56mm SD ± 3.27. The mean transverse diameter of the mitral annulus was 18.06 mm SD ± 2.93. Mean measurements from the tip of the anterior papillary muscle to the four fixed points in the annulus were 15.97mm, 17.82 mm, 11.95 mm and 16.57 mm. Measurements from the tip of the posterior papillary muscle to the four fixed points in the annulus were 16.20 mm, 13.58 mm, 12.35 mm and 14.97 mm. In cases where the tip of the papillary muscles was bifid, anterior papillary muscle bifidity was 60% and posterior papillary muscle was 30% and 10% in both the papillary muscles.

Conclusion: These distances are crucial in heart valve replacement surgeries for maintaining the continuity of the annulo-papillary apparatus. This continuity is also done using sutures. Hence a ready reckoner for measurements of the annulo papillary distance will give the operating surgeon a fair idea during prosthetic heart valve replacement surgeries.

Key words: Annulus, papillary muscle, mitral valve, left ventricle, leaflet and cusp.

INTRODUCTION

Prosthetic heart valve replacement surgeries are advocated for severe valvular heart disease. In persons who undergo artificial valve replacements, the quality of life improves post surgically. For an error free heart valve replacement, always special emphasis is placed on the continuity of the annulo papillary apparatus. This continuity is the crux for persons undergoing this prosthetic valve replacement and also for the operating surgeon.

Any alteration in the pre existing dimensions of the annulo papillary apparatus
will lead to complications like regurgitation and valvular incompetence. So it is imperative that a surgical procedure to replace the mitral valve has to be done very meticulously. The operating surgeon has to keep in mind about the biodynamic considerations before proceeding with a prosthetic valve replacement.

A prosthetic valve replacement done without taking the above mentioned factors can even result in a redo procedure which results in an increased incidence of morbidity and even a risk of mortality.

The mitral annulus is not a simple fibrous ring. It is made up of fibrocollagenous elements of varying consistencies from where the cusps take origin. These variations are the one which are responsible for changes in shape and size of the mitral annulus during the different phases of the cardiac cycle. The mitral annulus is structurally very strong transversely and is named as the trigones. The chordal struts are attached to the trigones as well as the anterior and posterior parts termed as prongs. The chordae arise from the papillary muscles support the mitral annulus. Frequently the tips of the papillary muscles are bifid. The papillary muscles, the mitral annulus, the chordae, cusps and the leaflets constitute the annulo papillary apparatus which is a very complex arrangement. During diastole ventricular filling occurs and during systole ventricular contraction takes place. Hence the contraction of the papillary muscle is precise which also results in increasing tension in the chordae prevents the valvular eversion and maintains competency of the mitral valve. The mitral valve undergoes changes in shape, position and area due to the complexity in arrangement. During systole the mitral valve is anterior and to the left and during diastole it is posterior and to the right. The surface area of the mitral annulus also reduces by about 40% during systole.

Due leverage has to given to these factors during prosthetic valve replacement.

The measurement of annulo papillary distance in cadaveric hearts holds relevance because it is observed that left ventricular end diastolic volume generally increases after valvuloplasty of mitral valve. Conventional mitral valve replacement without preservation of the annulo papillary apparatus continues to be associated with high prevalence of left ventricular functional disturbances postoperatively which results in an increased incidence of mortality. Preservation of the annulo papillary apparatus in valve replacement procedures leads to improvement of ventricular remodeling post surgically. Valve replacement surgeries resulted in increased long term survival after posterior leaflet preservation. Some authors have observed that even adequate Posterior leaflet preservation does not change hemodynamic valvular characteristics even after long term follow up.

**MATERIALS AND METHODS**

Fifty fresh cadaveric human hearts were made available for the study from the Departments of Anatomy and Forensic medicine of Vinayaka Missions Kirupananda Variyar Medical College, Salem. The following equipments were utilized for the study included dissecting instruments, digital vernier calipers, hand lens, measuring scale and digital camera.

The left atrium was incised both anteriorly as well as posteriorly to expose the mitral annulus. Four distinctive points were marked on each of the specimens which were equidistant (Fig-1). The first point was marked as A1 on right edge of the annulus. The second point was marked as A2 on the left edge of the annulus. The third point was marked as B1 on the anterior margin of the annulus equidistant between A1 and A2. The fourth point was marked as
B2 on the posterior margin of the annulus equidistant between A1 and A2. Measurements were taken from A1 to A2 which was the transverse diameter (Fig-2). Measurements were taken from B1 to B2 which was the vertical diameter. The left ventricle was incised alongside the margins to expose the papillary muscles (Fig-3).

Distances were also measured from the tip of both papillary muscles to the set points on the annulus. In specimens where the tip of the papillary muscles was bifid, distances from the highest point of the tip of the papillary muscle was measured from the annulus (Fig-4).

### Statistical Analysis

The measurements thus obtained were subjected to statistical analysis using SPSS software version 16. The range, standard deviation and mean were calculated. Paired “t” test (Table – 3) and chi square test (Table -2) was done to compare the variables.

### RESULTS

The mean distance between the tips of the anterior papillary muscle to the right edge of the annulus was 15.97 mm SD ± 2.86 (Table - 1). The mean distance from the tip of the posterior papillary muscle to the right edge of the annulus was 16.20 mm SD ± 3.50 (Table -1). The mean distance from the anterior papillary muscle to the left edge
of the annulus was 17.82 mm SD ± 3.57 (Table -1). The mean distance from the posterior papillary muscle to the left edge of the annulus was 13.58 mm SD ± 4.54 (Table -1). The mean distance between the tips of the anterior papillary muscle to the equidistant of posterior margin of the annulus was 11.95 mm SD ± 3.96 (Table -1). The mean distance between the tips of the posterior papillary muscle to the equidistant of anterior margin of the annulus was 12.35 mm SD ± 5.02 (Table -1). The mean distance from the posterior margin of the annulus was 14.97 mm SD ± 3.05 (Table -1). The mean vertical diameter was 16.56 mm SD ± 3.29 (Table – 1). The mean transverse diameter was 18.06 mm SD ± 2.93 (Table – 1).

In specimens with bifid papillary muscles, the incidence of bifidity of the anterior papillary muscle was 60% and in posterior papillary muscle was 30%. The bifidity in both anterior and posterior papillary muscle was 10% (Table – 4).

**DISCUSSION**

The importance of preserving the annulo papillary apparatus in mitral valve replacement procedures is repeatedly stressed upon due to post surgical complications. Due to erroneous measurements if a smaller valve is inserted, the annulus may become deformed and can result in perivascular leakage. **[8]** Preservation of the annulo papillary

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**Table: 1 Mitral valve annulo - papillary distances.**

<table>
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<tr>
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<tbody>
<tr>
<td>Mean</td>
<td>16.56</td>
<td>18.06</td>
<td>15.97</td>
<td>17.82</td>
<td>11.95</td>
<td>16.57</td>
<td>16.20</td>
<td>13.58</td>
<td>12.35</td>
<td>14.97</td>
</tr>
<tr>
<td>Minimum</td>
<td>24.56</td>
<td>26.85</td>
<td>22.64</td>
<td>25.09</td>
<td>21.70</td>
<td>25.05</td>
<td>24.70</td>
<td>23.99</td>
<td>24.46</td>
<td>23.50</td>
</tr>
<tr>
<td>Range</td>
<td>13.59</td>
<td>15.25</td>
<td>13.60</td>
<td>17.49</td>
<td>15.50</td>
<td>14.60</td>
<td>16.08</td>
<td>17.19</td>
<td>18.75</td>
<td>14.36</td>
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<tr>
<td>S.D</td>
<td>3.29</td>
<td>2.93</td>
<td>2.86</td>
<td>3.57</td>
<td>3.96</td>
<td>3.97</td>
<td>3.50</td>
<td>4.54</td>
<td>5.04</td>
<td>3.05</td>
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<tr>
<td>Variance</td>
<td>10.80</td>
<td>8.60</td>
<td>8.18</td>
<td>12.72</td>
<td>15.70</td>
<td>15.74</td>
<td>12.25</td>
<td>20.66</td>
<td>25.43</td>
<td>9.32</td>
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</table>

**Table: 2 Mitral annulo - papillary distance: Chi-square - Test**

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<tbody>
<tr>
<td>Chi-Square</td>
<td>3.760°</td>
<td>1.840°</td>
<td>3.760°</td>
<td>2.640°</td>
<td>1.840°</td>
<td>.000°</td>
<td>.960°</td>
<td>.960°</td>
<td>3.360°</td>
<td>.000°</td>
</tr>
<tr>
<td>Df</td>
<td>47</td>
<td>47</td>
<td>47</td>
<td>46</td>
<td>47</td>
<td>49</td>
<td>48</td>
<td>48</td>
<td>45</td>
<td>49</td>
</tr>
<tr>
<td>Asymp. Sig.</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
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</table>

| a.48 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.0. |
| b. 47 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.1. |
| c. 50 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.0. |
| d. 49 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.0. |
| e. 46 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.1. |

**Table: 3 Mitral annulo - papillary distances. Paired Samples ‘t’ Test.**

<table>
<thead>
<tr>
<th>Pair</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ant A1 - Post A1</td>
<td>-.22500</td>
<td>4.12235</td>
<td>.58299</td>
<td>-.39656 - .94656</td>
<td>-.386</td>
<td>49</td>
<td>.701</td>
</tr>
<tr>
<td>Ant A2 - POA2</td>
<td>.424060</td>
<td>3.60918</td>
<td>.51042</td>
<td>3.21488 - 5.26632</td>
<td>.920</td>
<td>49</td>
<td>.362</td>
</tr>
<tr>
<td>Ant B1- Post B1</td>
<td>-.39820</td>
<td>3.05907</td>
<td>.43262</td>
<td>-.126758 - 47118</td>
<td>.920</td>
<td>49</td>
<td>.362</td>
</tr>
<tr>
<td>Ant B2- Post B2</td>
<td>1.60600</td>
<td>3.62304</td>
<td>.51238</td>
<td>57094 - 2.63026</td>
<td>3.124</td>
<td>49</td>
<td>.003</td>
</tr>
</tbody>
</table>

**Table: 4 Bifidity of tip of papillary muscles of left ventricle.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Anterolateral</th>
<th>Posteromedial</th>
<th>Both</th>
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<tbody>
<tr>
<td>Total no. 50</td>
<td>30</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>Percentage</td>
<td>60%</td>
<td>30%</td>
<td>10%</td>
</tr>
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apparatus caused significant reduction in
diameters of the left ventricle, left atrium
and the right ventricle. [9] This outlook will
definitely lead to a reduction of the end
diastolic left ventricular length in long axis.
The distance between the fibrous trigones
will expand during regurgitation of the
mitral valve. This results in an increase in
the distance between the anterior and
posterior annulus. Hence the measurements
of the annulo papillary distances are bound
to give a fair idea in selection of a ring that
reduces the septolateral diameter and
reduces the intertrigonal distance of the
mitral valve. [10] Preoperative or
intraoperative determination of distance
between the tip of the papillary muscle and
the mitral annulus is very important in each
case of mitral valve replacement surgeries
because of the anatomical variations of the
papillary muscles. [3]

Surgical sutures may be prone to
disruption in patients with increased left
ventricular pressure and in hypertension. So
preservation of the annulo papillary apparatus enhances the area for attachment
in case of mitral valve replacement
procedures. [11] In persons with dilatation of
the left ventricle the chorda has to be longer
for proper closure of the mitral annulus. In
such cases when mitral valve replacement is
performed, the attachments are so placed
that, it does not affect the mitral valve
closure however measurements may prove
difficult during surgery. [12] Hence
approximate distances have to be measured
prior to procedure. In the present study there
is only a marginal difference in the distances
measured from the tips of the papillary
muscles to the annulus. In the distances
measured from the tips of the papillary
muscles to the left edge of the annulus did
not show any significant difference. In the
distances between the tips of the papillary
muscles and the posterior margin also did
d not show any significant difference (Table -
3). When these differences were statistically
analyzed, the corresponding “p” value was
less than 0.03 which is considered
statistically significant.

CONCLUSION

The preservation of the annulo
papillary apparatus is a must for good
prognosis in case of mitral valve
replacement. It is stressed through this study
that, Measurements of the distances between
the papillary muscles and the mitral annulus
should be taken into account for replacement
of mitral valve. The parameters and the
approximate distances obtained from the
present study may be taken as a guideline
for surgical replacement of mitral valve by
surgeons.

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literature for this article has been reviewed
and discussed. Authors are grateful to
IJHSR editorial board members and IJHSR
team of reviewers who have helped to bring
quality to this manuscript.

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