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Anatomical Proximity between Mitral Valve Annulus and Left Circumflex Artery – Implications to Mitral Valve Surgery

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KEYWORDS

Left circumflex artery, Mitral valve annulus, Mitral valve surgery

ABSTRACT:

Introduction: Mitral valve surgery raises the possibility of an acute myocardial infarction and iatrogenic injury to the left circumflex artery (LCX) which is closely tied to the mitral valve annulus (MVA)

Objectives: The objectives of this study is to develop a standardized anatomical distance from the LCX to the MVA and to better understand the relationship between coronary dominance and the LCX-MVA relationship in a clinically relevant setting.

Methods: 100 adult human hearts were obtained from the Forensic Department of Rajarajeshwari Medical College. The dominant pattern of the coronary arteries was analysed. Then left atriotomy was done, and three measurements were taken to determine MVA: anterior-posterior length, intercommissural length, and circumference. To report anatomical data in a clinically relevant context, a standardized clock face used in cardiothoracic surgery will be visually superimposed on the mitral valve annulus. The distance between LCX and MVA will thereafter be monitored every hour on the clock face where an artery is present.

Results: LCX was closest to MVA across all hearts at the P1 leaflet (8 o'clock) position. In right dominant hearts, the LCX was closest to the anterior commissure (10 o'clock) location. The left dominant heart's LCX was closer to the P3 leaflet (3 o'clock location). LCX was shown to be closest in left dominant arteries and female hearts.

Conclusions: This work improves awareness of the LCX-MVA interaction and reduces iatrogenic injury to LCX, allowing cardiac surgeons to avoid operational problems. This result validates earlier anatomical findings that left dominant hearts have a closer anatomical link with LCX and MVA

1. Introduction

Surgical intervention involving the Mitral valve involves possible impairment in the Left circumflex artery (LCX) blood flow because of its proximity to the mitral valve annulus (MVA).[1-7] The definite reason for such impediment of blood flow remains unanswered, although some plausible reasons include of direct suturing, laceration, or device distortion during mitral valve surgical repair.[7,8] Detecting such blood flow impairment during the surgical procedure can be difficult until irreversible lateral wall injury to the left

ventricle sets in culminating in left ventricular failure.[9] Although this complication affects 1.8% to 2.7% of individuals undergoing mitral valve surgical intervention, limited research is available on this entity.[10]

Limited research, comprising a limited number of cases, suggests that the closeness of the mitral annulus to adjacent coronary arteries, to the predominant configuration of the coronary network, is the underlying cause.[11,12]

This study improves understanding of the LCX-MVA relationship and prevents iatrogenic damage to LCX, assisting cardiac surgeons in preventing operative complications. This study also confirms previous anatomical findings that left dominant hearts have a closer anatomical relationship between LCX and MVA.

2. Objectives

The objectives of this study is to develop a standardized anatomical distance from the LCX to the MVA and to better understand the relationship between coronary dominance and the LCX-MVA relationship in a clinically relevant setting.

3. Materials and methods

3.1 Materials

For the purpose of this study, 100 fresh cadaveric human hearts were procured from Forensic department of Rajarajeshwari medical college and hospital.

Instruments used

Digital Vernier callipers

Dissection forceps (pointed, toothed, blunt)

Scalpel

Scissors

String to outline the annulus

3.2 Ethical consideration:

Ethical clearance is taken in 2019 from IEC of Rajarajeshwari medical college and hospital Bengaluru (RRMCH-IEC/175/2019-20) on 23/12/2019.

3.3 Inclusion and exclusion criteria:

Inclusion criteria: age group from 20 years to 60 year

Exclusion criteria: above 60 years and below 20 years

3.4 Study design:

The study population age ranges between 20-60 years consisting of 57 (57%) males and 43(43%) females. The methodology outlined below was applied to all hearts included in this study. The left circumflex artery (LCX) was dissected from the surrounding epicardial fat and distinguished from the coronary sinus located in the left atrioventricular groove. An analysis of the dominant pattern of the coronary arteries was conducted. A left atriotomy was performed, executing a longitudinal incision along the midline of the posterior atrial wall, located between the pulmonary veins and extending to the level of the mitral annulus. Following this, perpendicular incisions at the lower end of the longitudinal cuts created two flaps, which allowed for the exposure of the mitral valve leaflets and annulus. After performing the left atriotomy, three specific measurements were taken to evaluate the mitral valve annulus: the anterior-posterior length, inter-commissural length, and circumference. The anterior-posterior length was measured from the midline of the A2 leaflet to that of the P2 leaflet, while the inter-commissural length was measured from the anterior commissure to the posterior commissure. The circumference of the annulus was measured by tracing it with a string and measuring the resultant length. To contemplate anatomical data in a clinical context, a standardized clock face commonly used in cardiothoracic surgery was graphically superimposed on the mitral valve annulus. The midline of the A2 leaflet was designated as 12:00, and the midline of the P2 leaflet was marked at 6:00. The anterior and posterior commissures were positioned at 10:00 and 2:00 O'clock position, respectively. At each hour mark, the distance from the edge of the LCX to the mitral valve annulus was measured on the clock face while the artery was in place. Two independent observers conducted the measurements to the nearest 0.01 mm using a digital Vernier calliper, and the results were averaged to obtain the final value.

3.5 Statistical analysis:

Statistical analysis using a chi-square test was conducted to compare gender and dominance pattern. T-test was conducted to compare gender and mitral valve annulus measurements. The data of MV-LCX for gender are represented as mean + SEM and analysed by two-way repeated measures analysis of variance (RM ANOVA)

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for one factor repetition, and Bonferroni 't' test for post hoc multiple comparisons. Factor A, was gender (between group comparison – Male and Female), Factor B, was time series (within group comparison i.e., repetition factor – 1100, 1000, 0900, 0800, 0700, 0600, 0500, 0400 and 0300) and the gender X time series interaction. A probability of 0.05 and less was considered as statistically significant. SigmaPlot 14.5 version (Systat Software Inc., San Jose, USA) was used for statistical analysis and for plotting of graphs.

4. Results

4.1 Pattern of coronary dominance

72 heart specimens presented with right dominance pattern (38 male + 34 female),

17 with left dominance pattern (11 male+6 female) and 11(8 male + 3 female) with codominance pattern.

Table 4.1: Association of gender with dominance pattern.

S. No	Variable	Category	Male	Female	Statistics
1	Dominance pattern	Right	38	34	$\chi2$ = 2.046 P = 0.360
		Left	11	6	
		Codominant	8	3	

n = 100

The '$\chi2$' and 'P' values are by chi-square test.

4.2 Mitral Valve Annulus Characterization

Males showed higher average values for all mitral valve measurements than females, particularly in terms of annulus circumference (Table 3.2.1). In a study of 100 hearts, the average anterior-posterior length was 17.588 ± 0.562mm in males and 16.106± 0.540 mm in females, inter-commissural length was 40.054 ± 2.024 mm in males and 35.315±1.144mm in females, and annulus circumference was 112.921 ± 6.416 mm in males and 100.281±4.472mm in females.

Table 4.2.1: Comparison of Mitral valve measurements for gender

S.No.	Parameter	Gender	Mean	SE	Statistics
1	Antero-posterior Length (mm)	Male	17.588	0.0744	t = 13.280
		Female	16.106	0.0823	P < 0.001
2	Inter commissural Length (mm)	Male	40.054	0.268	t = 13.774
		Female	35.315	0.174	P < 0.001
3	Annulus Circumference (mm)	Male	112.921	0.850	t = 11.046
		Female	100.281	0.682	P < 0.001

n – Male = 57; Female = 43; Total = 100.

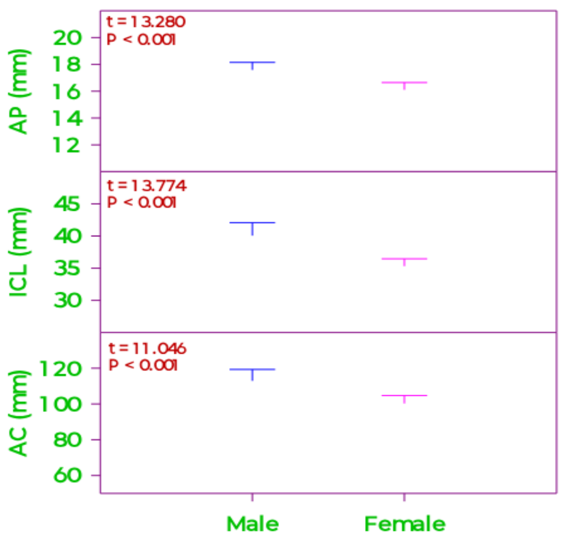
The 't' and 'P' values are by Student's 't' test.

Graph4.2.1: Comparison of Mitral valve measurements for gender.

The values are mean + SD.

n – Male = 57; Female = 43; Total = 100.

The 't' and 'P' values are by Student's 't' test.



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4.3 Circumflex Artery-Annulus Relationship

4.3.1 Overall Circumflex Artery-Annulus Relationship

Female hearts had a shorter average distance between LCX and the mitral valve annulus than male hearts throughout all hours on the mitral clock face.

The LCX was closest to the mitral valve annulus At 5:00 in all 100 hearts, with an average distance of 2.035 ± 0.254 mm in males and 1.503±0.292 in females.

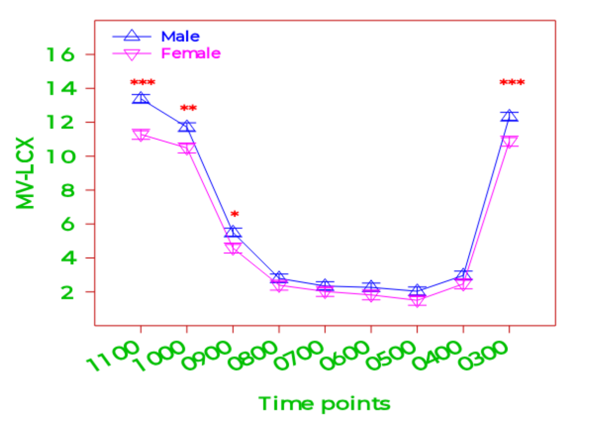
Table 4.3.1: Comparison of MV-LCX distance measurements for gender.

S.No.	Groups and comparisons	Standardized mitral valve clock face.	Statistics (mean ± SE)
1	Male	1100	13.380 ± 0.254
		1000	11.711 ± 0.254***
		0900	5.501 ± 0.254***
		0800	2.798 ± 0.254***
		0700	2.345 ± 0.254
		0600	2.264 ± 0.254
		0500	2.035 ± 0.254
		0400	2.970 ± 0.254*
		0300	12.331 ± 0.254***
2	Female	1100	11.284 ± 0.292
		1000	10.485 ± 0.292
		0900	4.583 ± 0.292***
		0800	2.394 ± 0.292***
		0700	2.026 ± 0.292
		0600	1.822 ± 0.292
		0500	1.503 ± 0.292
		0400	2.471 ± 0.292
		0300	10.879 ± 0.292***

n – Male = 57; Female = 43; Total = 100.

The SE is the combined standard error of the group.

***P < 0.001; **P < 0.01; *P < 0.05.



Graph 4.3.1:Comparison of MV-LCX distance measurements for gender.

Values are mean ± SE (n – Male = 57; Female = 43; Total = 100).

The SE is the combined standard error of the group.

The data was analysed by two-way RM ANOVA with Bonferroni’s’ test for multiple comparisons.

Significance between the genders - ***P < 0.001; **P < 0.01; *P < 0.05.

4.3.2 Right Dominant Circumflex Artery-Annulus Relationship

The shortest distance between the mitral annulus and the coronary arteries occurred at 5:00

The LCX was closest to the mitral valve annulus At 5:00 in all 100 hearts, with an average distance of 1.681± 0.187mm

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4.3.3 Left Dominant Circumflex Artery-Annulus Relationship

The shortest distance between the mitral annulus and the coronary arteries occurred at 5:00

The LCX was closest to the mitral valve annulus At 5:00 in all 100 hearts, with an average distance of 1.154± 0.385mm.

4.3.4 Co Dominant Circumflex Artery-Annulus Relationship

The shortest distance between the mitral annulus and the coronary arteries occurred at 5:00

The LCX was closest to the mitral valve annulus At 7:00 in all 100 hearts, with an average distance of 1.718± 0.479mm.

5. Discussion

The mitral annulus is a crucial component of the heart's central fibrous skeleton, forming connections with the AV node, LCX and Great cardiac vein. Accurate anatomical information is crucial for minimizing problems during MV intervention. The LCX is present in the left atrioventricular or coronary groove, nearby the mitral annulus. Characterization of the mitral valve annulus yielded results compatible with literature. The fibrous annulus varies between patients and can have a short anterior-posterior dimension.[13] Males showed higher MV measures than females, which is a common gender disparity in anatomical studies.

The prevalence of coronary dominance in the population remains a source of controversy. Reports vary from 58% right dominant, 10% left dominant, and 32% codominant, to 81.17% right dominant, 2.35% left dominant, and 16.47% codominant.14,15 In our study 72 heart specimens presented with right dominance pattern (38 male + 34 female), 17 with left dominance pattern (11 male+6 female) and 11(8 male + 3 female) with codominance pattern.

Many case reports show that the LCX is occluded at the anterior commissure, which is the closest site to the annulus.[5,6,13,16-18] The proximal LCX is at greater risk for iatrogenic injury due to its near proximity to the anterior commissure and wider width in left dominant hearts, as reported in numerous case studies.[8,14,19-21] Our investigation found that the distances recorded at the anterior commissure (10:00 position) were not consistently close across all hours. The 10:00 location was considerably different ($p<0.05$) from all other hours in right dominant hearts, showing that the LCX was much further from the annulus than the rest.

The average distance decreased significantly at the 9:00 position, showing a closer approach of the LCX to the mitral annulus between 10:00 and 9:00. The iatrogenic damage identified in the aforementioned case studies may have occurred in the transition zone between 10:00 and 9:00 positions, even if the injury was documented at10:00.

The LCX was closest to the mitral valve annulus At 5:00 in all 100 hearts, with an average distance of 2.035 ± 0.254 mm in males and1.503±0.292 in females.

Previous studies have explored how coronary dominance affects the LCX's closeness to the mitral annulus. According to Kaklikkaya and Yenigolu, the distance between the LCX and the fibrous annulus directly correlates with coronary dominance.[14] Their study found that left dominant circulation had shorter distances than both right and co-dominant hearts, with the circumflex reaching as near to the annulus as 1 mm in some cases. Our data shows that fresh left dominant hearts have an average circumflex-mitral annulus distance of <1 mm during 8:00-4:00.

Pessa et al. (2004) found no correlation between the circumflex-annulus distance and coronary network dominance patterns.[15] There have only been 5 reports of iatrogenic injury in the right dominant system.[12,20,22-24] Pessa et al. found that right dominant hearts have a minimum distance of 1.01 mm between the LCX and annulus.[15] Our investigation found that right dominant hearts had longer average distance between 9:00-4:00 positions, indicating a lower likelihood of iatrogenic injury after surgery. Except for 10:00, 11:00 and 3:00, left dominant hearts were constantly closer to the mitral annulus compared to right dominant hearts. These findings suggest that left dominant hearts have a stronger interaction with the LCX-annulus. Except for 10:00, 11:00 and 3:00, hearts were constantly closer to the mitral annulus compared to right dominant hearts.

This new research suggests using cautionary sutures in previously thought-to-be low-risk locations during mitral valve surgery. Mitral valve repair and arrhythmia surgery use a left atrial isthmus ablation line that spans the posterior portion of the mitral annulus at 4:00/5:00. This line is thought to be a safe zone for LCX ablation procedures. Our findings suggests that ablation is more effective in patients with a left dominant circulation. To reduce the danger of LCX injury, updated procedures involve performing radiofrequency ablation (RFA) between the left pulmonary veins and mitral annulus, further away from the atrioventricular groove after the terminal LCX has exited the groove.[25] Preoperative coronary angiography is crucial for determining a patient's coronary dominance, and caution should be exercised in left or co-dominant patients, based on our findings.[24,26]

6. Conclusion

This study supports prior findings that left-dominant hearts had a closer LCX-annulus connection. These findings are significant for atrial fibrillation surgery, as cardiac ablation treatments typically take place between 4:00-5:00, putting patients with left dominant LCX at higher risk of iatrogenic damage. Future research should focus on how the anterior leaflet, which is in fibrous continuity with the aortic valve, is affected by the same three mitral valve procedures.

Conflict of interest: None to be declared by all the authors.

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