Damage to Coronary Arteries during Mitral Valve Surgery

Dr. Kaklikkaya

(#2003-99087 . . . July 19, 2003)

Islam Kaklikkaya, MD, PhD,[1] Gulay Yeginoglu, MS, PhD[2]

Departments of [1]Thoracic and Cardiovascular Surgery and [2]Anatomy, Faculty of Medicine, Karadeniz Technical University, Trabzon, Turkey

ABSTRACT

Background: The rheumatic cardiac valve diseases are one of the most important heart problems in Turkey. In mitral valve surgery, the relationship between the anulus fibrosus sinister and the coronary arteries is extremely critical for the postoperative life of the patient.

Methods: The study was performed with human adult hearts. The aim of this study of 50 hearts was to understand the existing correlations between the mitral annulus and the coronary arteries. We determined the right or left dominance or codominance of the anulus fibrosus sinister on each heart and studied the relationship of the mitral annulus to the circumflex coronary artery (CCA) and the left posterior descending coronary artery.

Results: The distances of the anulus fibrosus sinister from the CCA and interventricularis posterior arteries were measured with a flexible ruler. In 19 of 50 cases, the distance of the coronary artery from the annulus was 3 mm at 23 different points, 2 mm at 8 different points, and 1 mm at 2 different points.

Conclusions: In mitral valve surgery, damage to the CCA can occur, especially in patients with left coronary dominance or codominance in which the CCA is running in the atrioventricular groove very close to the mitral annulus. Therefore, this study emphasizes the importance of knowing the coronary artery anatomy preoperatively.

INTRODUCTION

The predominant cause of mitral stenosis is rheumatic fever [Olson 1987]. Rheumatic fever results in the fusion of the mitral valve apparatus leading to stenosis. The stenotic mitral valve is typically funnel-shaped, and the orifice is frequently shaped like a "fish mount" or a buttonhole, with calcium deposits in the valve leaflets sometimes extending to involve the valve ring, which may become quite thick [Waller 1986].

Mitral valve repair or replacement has become the procedure of choice for patients with mitral valve disease, and the long-term results have been promising [Deloche 1990]. Many patients with chronic mitral stenosis require valve replacement. Because significant dystrophic changes, including marked thickening and shortening of all chordae, obliteration of the valvular space, agglutination of the papillary muscles, and calcification in both annular and leaflet tissue, may develop on a valve, aggressive decalcification and heroic reconstructive techniques for these extremely advanced pathologic valves generally produce poor long-term results [Edmunds 1997]. In mitral valve reconstruction/replacement, damage to the circumflex coronary artery (CCA) can occur. This risk is not frequently discussed, although it has been classically defined. Therefore, we have undertaken an anatomical study to understand the importance of this risk.

MATERIALS AND METHODS

The anatomical study was carried out on 50 adult hearts from autopsy cases in the Trabzon branch of the Institute of Forensic Medicine (Republic of Turkey, Ministry of Justice). Dissection was done macroscopically on these normal fresh hearts. Hearts from individuals deceased for more than 12 hours, hearts that were morphologically putrid cases for any reason, and hearts from cases of dilated cardiomyopathy, valvular disease, and congenital heart disease were not included.

We determined the right coronary dominance, left coronary dominance, or codominance of the coronary network for each heart and studied the relationship of mitral annulus to the circumflex artery and the posterior descending artery.

Coronary dominance is defined by the positions of the left and right coronary networks as described by the National Heart, Lung, and Blood Institute (Figure 1) [NHLBI 1993]. In left dominance, the left CCA courses along the atrioventricular groove and, in 10% to 15% of patients, continues around the atrioventricular artery to the crus of the heart to give rise to the posterior descending artery. The primary branches of the left CCA are the obtuse marginals. They supply blood to the lateral wall of the left ventricular myocardium, including the posteromedial papillary muscle. Additional branches supply blood to the left atrium and, in 40% to 50% of hearts, to the sinus node. When the CCA supplies the posterior descending artery, it also supplies the atrioventricular node [Edmunds 1997].

In right-dominant circulation, the right coronary artery courses from the aorta anteriorly and laterally before descending in the right atrioventricular groove and curving

Received May 14, 2003; received in revised form July 16, 2003; accepted July 19, 2003.

Address correspondence and reprint requests to: Islam Kaklikkaya, MD, PhD, K.T.U. Lojmanları No: 30/13, 61080 Trabzon, Turkey; 90-462-3775506; fax: 90-462-3252821 (e-mail: ikaklikkaya@yahoo.com).

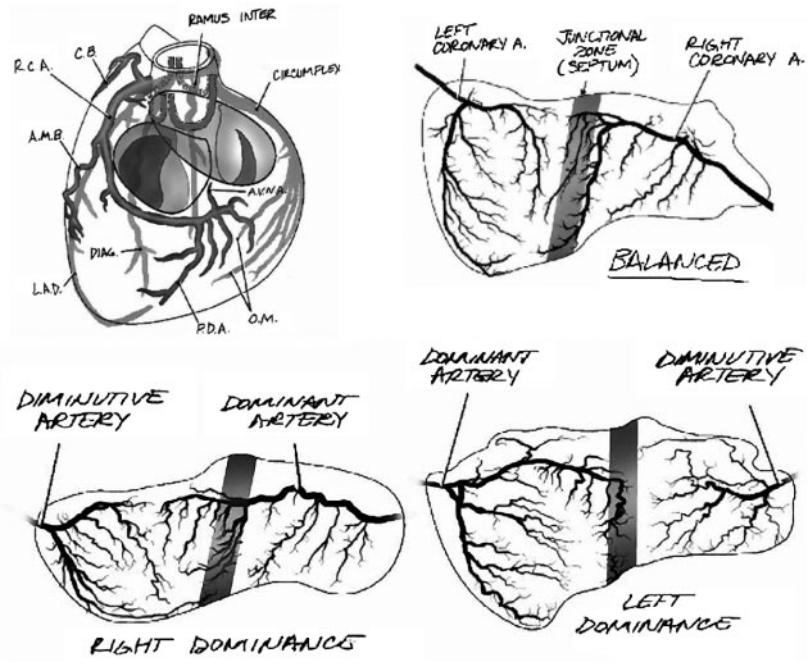

Figure 1. Dominant right coronary, dominant left coronary, and balanced coronary networks. Ramus inter. indicates ramus interventricularis; C.B., circumflex branch; R.C.A., right coronary artery; A.V.N.A., atrioventricular node artery; A.M.B., anteromedial branch; Diag., diagonal; L.A.D., left anterior descending coronary artery; P.D.A., posterior descending coronary artery; O.M., obtuse marginal arteries.

posteriorly at the acute margin of the right ventricle. In 85% to 90% of hearts, the right coronary artery crosses the crus, where it makes a characteristic U-turn before bifurcating into the posterior descending artery and the right posterolateral artery. In 50% to 60% of hearts, the artery to the sinus node arises from the proximal portion of the right coronary artery. The blood supply to the atrioventricular node arises from the midportion of the U-shaped segment. The posterior descending artery runs along the posterior interventricular groove, extending for a variable distance toward the apex of the heart [NHLBI 1993, Edmunds 1997].

In the codominant circulation system, the inferior surface of the left ventricle is vascularized by the left main artery coming from the right coronary and circumflex arteries. The posterior interventricular artery comes from the right coronary artery in 34% of hearts [NHLBI 1993].

The left atrium was excised in parallel from 2 cm over the sinus coronarius instead of the atrioventricular groove (Figure 2). After the CCA was determined by following the left main coronary artery through to the aorta, the progress of the artery through the mitral valve annulus was observed by dissecting left atrial tissue.

Over the posterior leaflet on the mitral annulus, 5 relative points were determined and marked (Figure 2). The first point was located at the level of the anterior commissure, and the last point was located at the level of posterior commissure. The other points were equally spaced between these two points. From these 5 points, the distances between the mitral annulus and the closest coronary artery were measured by using a flexible ruler. The closest coronary arteries were the CCA at points 1 and 2 and the right posterior descending coronary artery at points 4 and 5. Whereas the right posterior descending coronary artery continued at point 3 in the hearts with right-dominant circulation, the artery at point 3 was a continuation of the left CCA in the hearts with left-dominant and codominant systems.

RESULTS

This work was carried out on the hearts of 50 individuals, 28 men (56%) and 22 women (44%). The ages of the youngest and oldest individuals were 18 years and 58 years, and the mean age was 29.58 years. The hearts were divided

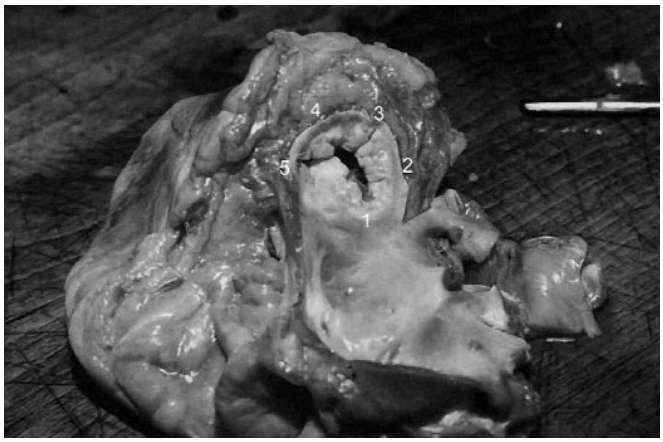

Figure 2. Left atria were excised, and 5 relative points were determined and marked.

Distances between the Coronary Artery and the Mitral Annulus*

Points	Coronary Artery	Distance, mm		
		Group 1 (n = 29; 58%)	Group 2 (n = 16; 32%)	Group 3 (n = 5; 10%)
1	Circumflex	6.72 ± 1.51	3.72 ± 0.93	3.10 ± 0.74
2	Circumflex	5.20 ± 1.26	3.00 ± 0.97	2.30 ± 1.10
3	Circumflex or posterior descending	6.69 ± 1.42	4.91 ± 1.47	3.50 ± 0.87
4	Posterior descending	5.10 ± 1.23	6.72 ± 1.34	4.80 ± 0.84
5	Posterior descending or AV node artery	6.69 ± 1.51	7.75 ± 1.95	5.80 ± 0.57

*Data are presented as the mean ± SD. AV indicates atrioventricular.

into 3 groups: right-dominant (group 1) with 29 cases (58%); codominant (group 2) with 16 cases (32%); and left-dominant (group 3) with 5 cases (Table).

In group 1, the distances between the coronary artery and the mitral annulus ranged from 4 to 10 mm, and the mean distances were 6.72 ± 1.51 mm at point 1, 5.20 ± 1.26 mm at point 2, and 5.10 ± 1.23 mm at point 4 (Figure 3).

In group 2, the distances between the coronary artery and the mitral annulus ranged from 1 to 10 mm, and the mean distances were 3.72 ± 0.93 mm at point 1, 3.00 ± 0.97 mm at point 2, and 7.75 ± 1.95 mm at point 5 (Figure 4). The distance at point 2 was 1 mm in 1 case and 2 mm in 4 cases. A distance of 3 mm was observed at point 1 in 7 cases, at point 2 in 5 cases, and at point 3 in 2 cases (Figure 4).

In group 3, the distances between the coronary artery and the mitral annulus ranged from 1 to 6.5 mm, and the mean distances were 3.10 ± 0.74 mm at point 1, 2.30 ± 1.10 mm at point 2, and 5.80 ± 0.57 mm at point 5 (Figure 5). The distance at point 2 was 1 mm in 1 case and 2 mm in 2 cases. A distance of 2 mm was observed at point 1 in one case, and a distance of 3 mm was observed at point 1 in 2 cases and at point 3 in 3 cases (Figure 5).

DISCUSSION

The distribution of the coronary arteries on hearts varies significantly, and the position of the posterior descending coronary artery is often taken as the origin. According to the classification by the National Heart, Lung, and Blood Institute of the United States, the arteria coronaria cordis dextra is accepted as indicative of right-dominant circulation if it vascularizes the posterior descending coronary artery. It supplies blood to the diaphragmatic side of the ventriculus cordis sinister. If the posterior descending branch is a continuation of the left CCA, the configuration is called left dominance, and if the posterior descending branch vascularizes together with or without the arteria coronaria cordis dextra and the ramus circumflexus, the configuration is called a codominant or balanced network [NHLBI 1993].

Researchers have observed different distributions of right-dominant circulation. The frequency of right dominance has been reported to be 75% [Grondin 1996], 60% [Williams 1995], 89% [Nerantzis 1996], 85% to 90% [Edmunds 1997], 77% [Virmani 1982], 40% [Leguerrier 1977], 58% [Christides 1976], and 33% [Cornu 1995]. In the present study, the frequency of right-dominant coronary circulation was determined to be 58% (Table).

When left-dominant coronary circulation presents, the posterior descending coronary artery is the last branch of the left circumflexus coronary artery, and the ramus circumflexus supplies blood to the diaphragmatic and lateral sides of ventriculus cordis sinister. The frequencies of left dominance have been reported to be 8% [Virmani 1982], 10% to 15% [Kirklin 1993, Edmunds 1997], and 10% [Christides 1976, Leguerrier 1977, Williams 1995, Grondin 1996]. Cornu et al [Cornu 1995] did not encounter any cases of left-dominant

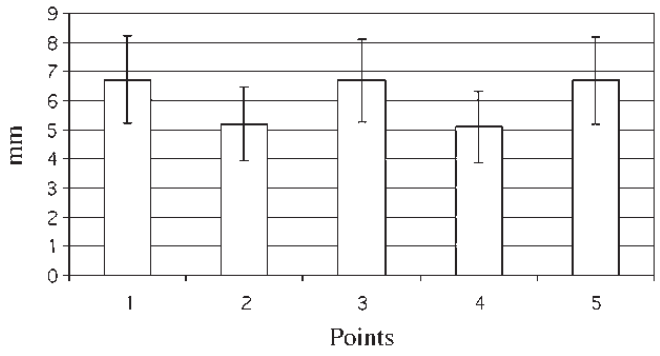

Figure 3. The distribution of distances between the coronary artery and the mitral annulus in the right-dominant hearts (group 1) at the 5 application points (n = 29).

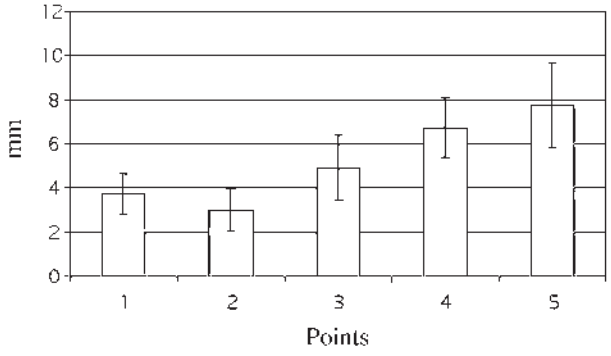

Figure 4. The distribution of distances between the coronary artery and the mitral annulus in the codominant hearts (group 2) at the 5 application points (n = 16).

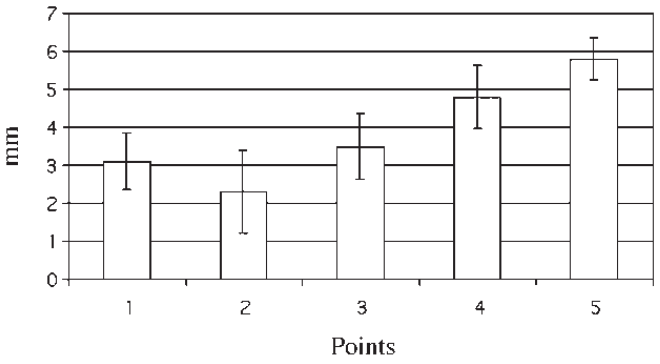

Figure 5. The distribution of distances between the coronary artery and the mitral annulus in the left-dominant hearts (group 3) at the 5 application points (n = 5).

coronary circulation in their series. In our study, we observed a 10% incidence of left dominance (Figure 4) (Table).

In a balanced network, the arteria coronaria cordis dextra and the ramus circumflexus supply blood to the inferior surface of the left ventricle. Branches of both arteries are distributed in the interventricular sulcus or are vascularized in parallel. In this study, the frequency of codominance was found to be 32% (16 hearts) (Table), whereas the frequency has elsewhere been reported to be 67% [Cornu 1995], 55% [Leguerrier 1977], 32% [Christides 1976], 15% [Virmani 1982], 10% [Grondin 1996], and 30% [Williams 1995].

The aim of this study was to determine the anatomical relationships between the anulus fibrosus sinister and the arteria coronaria cordis and their branches for patients undergoing mitral valve surgery, because there are relatively few reports on this subject [Leguerrier 1977, Virmani 1982, Cornu 1995]. Virmani and coworkers [Virmani 1982] investigated the distances between the CCA and the anulus fibrosus sinister on 15 hearts and observed a direct relationship with dominant coronary type. They determined the distance from the CCA to the anulus fibrosus sinister to range between 3 mm and 6.5 mm with a mean of 4.1 mm in left-dominant hearts. In our study, we observed 5 left-dominant hearts, and the distances varied between 1 mm and 6.5 mm. The mean values were 2.30 ± 1.10 mm at point 2 and 5.80 ± 0.57 at point 5. However, Danielson and coworkers [Danielson 1967] in their 31-case study indicated no differentiation of dominant circulation and reported this distance to range from 1.5 to 12 mm with a mean of 5.5 mm. Virmani et al [Virmani 1982] showed that this distance ranged from 4.5 to 7.5 mm with a mean of 5.5 mm for codominant hearts in which the posterior descending coronary artery was vascularized from the CCA. Cornu et al [Cornu 1995] did not observe any left-dominant hearts in their 15-case study and reported the distances from the CCA to the anulus fibrosus sinister in 10 codominant hearts to range from 1 to 15 mm and to be generally less than 6 mm with a mean of 5.74 mm.

The CCA has been reported to sometimes be in contact with the anteromedial commissure of the anulus fibrosus sinister [Cornu 1995]. In our study, however, we observed 16 codominant hearts, and the CCAs were 1 to 13 mm from the anulus fibrosus sinister with a mean of 3.00 ± 0.97 mm at point 2 and 7.75 ± 1.95 mm at point 5.

Previously, it was documented that the cases involving two patients with mitral valve replacement and one patient with mitral valve anuloplasty with a Carpentier-Edwards ring resulted in the binding of the CCA [Virmani 1982].

Tavilla and Pacini [Tavilla 1998] reported that a left-dominant patient who underwent a mitral valve repair with a sliding leaflet technique showed transmural posterior and inferior ischemia in an intraoperative electrocardiogram and therefore underwent an additional saphenous vein bypass graft to the posterolateral branch of the CCA. The patient was weaned from cardiopulmonary bypass without incident [Tavilla 1998].

Virmani et al [Virmani 1982] showed that the distance between the CCA and the anulus fibrosus sinister in right-dominant hearts was between 6 mm and 11.5 mm with a mean of 8.4 mm, whereas Cornu et al [Cornu 1995] determined this distance to be between 6 mm and 10 mm with a mean of 6.70 mm. In our study, we investigated 29 right-dominant hearts and found the coronary artery to be 4 to 10 mm from the anulus fibrosus sinister with mean values of 6.72 ± 1.51 mm at point 1, 5.20 ± 1.26 mm at point 2, and 6.69 ± 1.42 mm at point 3 (Table). Our results indicate that the coronary arteries are closer to the anulus fibrosus sinister than reported by Virmani et al [Virmani 1982]. These findings, together with the information reported for other cases, support the conclusion that the distances between the CCA and the anulus fibrosus sinister in right-dominant circulation cases are always operatively more favorable than those in left-dominant cases. This conclusion is consistent with the fact that there has been no report of any coronary artery injury in right-dominant hearts during mitral valve surgery [Cornu 1995].

Rheumatic mitral valve disease is frequently seen in the northeast region of Turkey. In recent years, mitral valve replacement or valve repair has been used to treat these patients. Some of the condition's characteristics, such as calcification, stretching of the anulus fibrosus sinister and the musculus papillaris, fibrosis, the atrioventricular fat content, rereplacement, and the ethnic origin of the patient, affect the distance from the anulus fibrosus sinister to the ramus circumflexus [Danielson 1967, Minami 1989, Dhawan 1995, Tokunaga 1995, Speziale 1998].

As can be concluded from the present results, there is a risk of injury to the CCA in left-dominant and codominant hearts during mitral valve surgery. Danielson et al [Danielson 1967] reported the binding of the CCA during mitral valve surgery in 2 patients with a left-dominant coronary system and in 1 patient with a codominant heart and indicated that anulus fibrosus sinister calcification was the main reason.

In our study, the mean distance at point 2 was 2.30 ± 1.10 mm in group 3 and 3.00 ± 0.97 mm in group 2 (Table). These results indicate that the probability of injury is greater on the proximal one third of the CCA. The risk of suturing the coronary artery increases if the ring is located just behind the mitral valve anulus during anuloplasty.

In conclusion, coronary angiography should be applied to prevent any injury to the CCA during mitral valve surgery, and, if possible, the dominant coronary artery should be determined.

Those sutures to be located in the anulus fibrosus sinister for at least half of the anterior commissure of the posterior cusp of the mitral valve have to be carefully applied to the heart with left-dominant and codominant coronary circulation. A mitral valve or ring prosthesis should be adequately secured but with limited deepness to prevent any injury to the CCA.

During redo prosthetic valve surgery, it might be difficult to withdraw the implanted prosthesis if there is any presentation of serious pannus formation. Aorta–coronary artery bypass to the distal CCA saves lives if cardiopulmonary bypass is not discontinued in cases of anulus fibrosus sinister calcification, rereplacement, or anuloplasty or if arrhythmia or resistant ventricular fibrillation occurs.

REFERENCES

Christides C, Cabrol C. 1976. Anomalies de trajet et de division des arteres coronaires et de luers branches. Bull Assoc Anat (Nancy) 60:655-61.

Cornu E, Lacroix PH, Christides C, Laskar M. 1995. Coronary artery damage during mitral valve replacement. J Cardiovasc Surg (Torino) 36:261-4.

Danielson GK, Cooper E, Tweedore DN. 1967. Circumflex coronary injury during mitral valve replacement. Ann Thorac Surg 4:53-9.

Deloche A, Jebara VA, Relland JY, et al. 1990. Valve repair with Carpentier technique: the second decade. J Thorac Cardiovasc Surg 99:990-1002.

Dhawan J, Bray CL. 1995. Are Asian coronary arteries smaller than Caucasian? A study on angiographic coronary artery size estimation during life. Int J Cardiol 49:267-9.

Edmunds LH. 1997. Cardiac surgery in the adult. New York, NY: McGraw-Hill. p 35-57.

Grondin MC. 1996. Surgical anatomy of the coronary arteries. In: Baue EA, Geha SA, Laks H, Hammond LG, Naunheim SK, editors. Glenn's thoracic and cardiovascular surgery. London, UK: Prentice-Hall International. p 2057-65.

Kirklin JW, Barratt-Boyes BG. 1993. Cardiac surgery. New York, NY: Churchill Livingstone. p 3-59.

Leguerrier A. 1977. Les arteres coronaires: etude anatomique de 120 coeurs. Gaz Med Fr 20:2143-52.

Minami KT, Fergusson DJ. 1989. Systolic compression of the right coronary by a pseudoaneurysm following mitral valve replacement. Catheter Cardiovasc Diagn 18:31-5.

Nerantzis CE, Papachristos JC, Gribizi JE, Voudris VA, Infantis GP, Koroxenidis GT. 1996. Functional dominance of the right coronary artery: incidence in the human heart. Clin Anat 9:10-3.

[NHLBI] National Heart, Lung, and Blood Institute. 1993. Proposal and manual of operations for collaborative studies in coronary artery surgery: contract no. I-HV-32973: National Heart, Lung, and Blood Institute, Washington, DC: 1975. In: Kirklin JW, Barratt-Boyes BG, editors. Cardiac surgery. New York, NY: Churchill Livingstone. p 18-9.

Olson LJ, Subramanian R, Ackermann DM, Orszulak TA, Edwards WD. 1987. Surgical pathology of the mitral valve: a study of 712 cases spanning 21 years. Mayo Clin Proc 62:22-34.

Speziale G, Fattouch K, Ruvolo G, Fiorenza G, Papalia U, Marino B. 1998. Myocardial infarction caused by compression of anomalous circumflex coronary artery after mitral valve replacement. Minerva Cardioangiol 46:455-6.

Tavilla G, Pacini D. 1998. Damage to the circumflex coronary artery during mitral valve repair with sliding leaflet technique. Ann Thorac Surg 66:2091-3.

Tokunaga S, Yoshitoshi M, Mayumi H, et al. 1995. Left ventricular-coronary sinus shunt through a septal aneurysm after mitral valve re-replacement. Ann Thorac Surg 59:224-7.

Virmani R, Chun PK, Parker J, McAllister MA Jr. 1982. Suture obliteration of the circumflex coronary artery in three patients undergoing mitral valve operation: role of left dominant or codominant coronary artery. Thorac Cardiovasc Surg 84:773-8.

Waller BF. 1986. Rheumatic and non rheumatic conditions producing valvular heart disease. In: Frankl WS, Brest AN, editors. Cardiovascular clinics. Valvular heart disease: comprehensive evaluation and management. Philadelphia, Pa: F. A. Davis. p 3-104.

Williams PL, Bannister LH, Berry MM, et al, editors. 1995. Gray's anatomy. 38th ed. London, UK: Churchill Livingstone. p 1475-1500.