A Morphological Study on the Coronary Ostia In Human Autopsy Hearts

With Special References on the Funnel-Shaped Structure, Overhang
Phenomenon and Their Clinical Significance

Tatsuji KANO, M D, Ryozo OKADA, M D,
and Kazuo KITAMURA, M D

Cardiology, The Department of Internal Medicine, School
of Medicine, Juntendo University

A morphological study on the coronary ostia was performed in 70 autopsied human hearts, with particular attention focused on its funnel-shaped structure, its aging changes and relation to atherosclerosis. The following results were obtained in this study, 1) There are great varieties in the funnel-shaped structure of the coronary ostia. However, a double circular shape in the right ostium, and a comet shape in the left are commonly seen. 2) The funnel-shaped structure of the coronary ostia is characterized by longitudinal smooth muscle arrangement in the inner layer and circular in the outer one. 3) Atherosclerosis and the overhang phenomenon tend to be more severe in the right ostium than the left. 4) The incidence of significant ostial stenosis due to atherosclerosis is: 7 out of 70 cases in the right; 3 in the left, and 4 cases in both sides. Among 14 cases of ostial stenosis, there are 4 cases of myocardial infarction. Thus, the incidence of myocardial infarction is more common in cases of ostial stenosis than in those without stenosis. 5) In ischemic heart diseases, not only sclerotic changes in the coronary arteries themselves, but changes in the ostia of the coronary arteries should be given serious consideration.

Key Words: Leonardo da Vinci, Coronary ostium, Funnel-Shaped structure, Overhang phenomenon, Myocardial infarction, Ischemic heart disease

Though many pathological studies have been performed on coronary sclerosis and aortic sclerosis, as yet there have been few studies of the coronary ostium in Japan, as elsewhere. Clinically, surgical treatment of coronary heart disease has become routine and obtains successful results. Mo-

reover, when the stenosis is limited to the coronary ostial area, surgical correction should be most helpful. In addition, selective coronary angiography is now being conducted extensively. Therefore, knowledge of the coronary ostial morphology is imperative for all internists and surgeons working in cardiology.

It is of considerable interest that the 15th century artist Leonardo da Vinci made a sketch of the coronary ostium. In it, a whorl-like design is found on the portion compatible with the sinus of

Received for publication August 30, 1976.

Reprint requests to: Tatsuji Kanoh, Cardiology, Department of Internal Medicine, Juntendo University, 1-1-2, Hongo, Bunkyo-ku, Tokyo, 113, Japan.

Fig. 1. A Sketch by Leonardo da Vinci

Valsalva and the coronary ostium is clearly shown with a hole on both the left and right sides (Fig. 1)¹⁾. The authors focused their attention on this sketch, which reflects the artistic genius of the Renaissance era, with particular interest as to whether this whorl-like structure really exists or not. Studies were made on autopsied human hearts as to the shape and size of the normal coronary ostium and the changes according to aging and related to atherosclerosis.

MATERIALS AND METHODS

Materials consisted of 70 unselected autopsied hearts at the Department of Pathology, School of Medicine, Juntendo University. The cases examined were 50 males

and 20 females. Their ages ranged from 17 to 89 year-old, of which eight cases were under 30, nine between 31 and 50, 37 between 51 and 70 and 16 over 71. Respective cause of death was as follows: malignant tumor, 34; myocardial infarction, 7; uremia, 6; diabetes mellitus, 4; cirrhosis of the liver, 5; brain tumor, 4; cerebrovascular accident, 3; and others, 7. Macroscopic examination of the aorta and heart was performed after formalin fixation. The coronary ostium of each case was macroscopically sketched as to its shape, location and surroundings of the atherosclerosis. The size of the coronary ostium was measured horizontally and vertically with a micrometer at a stretch pressure condition and the area was calculated to be an ellipse. Longitudinal and cross-section blocks, including the entrance of the sinus of Valsalva, were obtained for embedding into paraffin after re-fixation with 0.5% acetyltrimethyl ammonium bromide added formalin. The slices were cut at 7μ and stained with hematoxylin eosin, azan, Elastica-van Gieson and PAS methods for microscopic examination. In three cases, the longitudinal and cross-section blocks were cut serially for close study of the unique structure of the ostium. With regard to atherosclerosis of the aorta, the extent and quality of the lesions were estimated according to Gore's method²⁾. The extent of change was classified into five stages, with 0 showing disease spreading of less than 5% (negligible), A representing 6 to 15% (minimal), B representing 16 to 33 (mild), C representing 34 to 50% (moderate) and D representing 51 to 100% (severe) of the estimated surface. The type of atherosclerotic lesion was macroscopically classified into four degrees. The first was fatty streaks, spots and plaques; the second was fibrous plaque; the third was atheromatous plaque with ulceration, necrosis, or hemorrhage; the fourth was atheromatous calcified plaques. The aforementioned index of the extent and quality of atherosclerosis was applied to coronary sclerosis according to the WHO and Gore's

methods^{2,3)}. The left and right coronary arteries were examined by cut cross-section from the main trunk to distal at 3 mm intervals and the narrowing of the lumen was examined and grouped into six stages. Zero indicates the nonexistence of stenosis; 1 is a minimal stenosis; 2 is over 25%; 3 is over 50%; 4 is over 75%, and 5 indicates complete occlusion. The left anterior descending branch, the circumflex branch and the right coronary artery where the maximum degree of stenosis was found were totalled and the coronary sclerotic index was obtained.

RESULTS

A) Macroscopic study of the coronary ostium

1) The funnel-shaped structure of the coronary ostium

There is a well-defined dimple at the coronary ostial area and, in most cases, the lower entrance of the funnel-shaped structure reveals an opening. The shapes of the funnel-shaped structure vary and are classified into six basic types: double circular, long and slim, elliptic, reverse triangular, comet and flat (Fig. 2). On the right ostium, the most common shape is double circular, followed by flat, long and slim and elliptic; whereas on the left ostium, the comet shape is predominant with 60% of the total. The funnel-shaped structure becomes more noticeable with age, penetration becoming serious and with a tendency for the boundary to become more distinct.

Fig. 2. Macroscopic view of the coronary ostium

2) The overhang phenomenon and atherosclerosis around the coronary ostium

Fig. 3. Microscopic view of the coronary ostium. Upper portion shows the overhang phenomenon (longitudinal section, Elastica-van Gieson stain, 12x.)

In the area around the coronary ostium, especially at the upper margin, there is a swelling caused by fibrosis and atheroma, as if the ostium is covered by an overhang (Fig. 3). The authors named this the "Overhang Phenomenon". It becomes more severe with aging and the progress of atherosclerosis and its incidence is different between the left (11.6%) and right (46.3%) sides. The location of the overhang differs on the right and left ostia. On the right, it appears on the upper margin of the ostium; and on the left at the upper right margin (Fig. 4). If represented as on the face of a clock, the right coronary ostia are mainly at the 10 o'clock to 2 o'clock position, or at the upper margin of the

Fig. 4. Schematic presentation of the location of overhang.

Fig. 5. Location of atherosclerotic plaques around the coronary ostium.

funnel portion, and the left mainly at the 9 o'clock to 12 o'clock position or the upper right margin (Fig. 5). The location of maximal ostial atherosclerosis is identical to that of the overhang. The grade of the coronary ostial atherosclerosis was classified into four degrees—negligible, mild, moderate and severe—and a study was made of the progress of aortic sclerosis on the right and left coronary ostia according to age.

Degree	Age			
	~ 30	31~50	51~70	71~
Negligible	R: ••	••••••	••	•
	L: •••••	••••••	••••••	••••••
Mild	R: ••••	••••••	••••••	••••••
	L: ••	•••	•••••	•••••
Moderate	R: •		••••••	••••••
	L:		••••••	••••••
Severe	R:		•	••
	L:			••

R: Right
L: Left
•: Obstruction

Fig. 6. Age and grade of atherosclerosis of the coronary ostium.

In patients up to 50 years old, the sclerosis is mild and differences between the right and left ostia are not noticeable. In patients over 50, the sclerosis varies between the right and left sides. There is severe aortic sclerosis, and it is overwhelmingly pronounced on the right ostial side, with three cases on the left and 13 cases on the right (Fig. 6).

3) The coronary ostial area

The coronary ostial area tends to spread with aging. In all 70 cases, the average area of the coronary artery ostium is 23.5 mm² on the left and 16.6mm² on the right. There are 11 instances of abnormal narrowing of the coronary ostial area on the right side and seven on the left. Moreover among the 13 cases of advanced atherosclerosis of the aorta, there are five or 38.4% where the condition had reached to the coronary ostium causing ostial stenosis.

4) Coronary ostial sclerosis and coronary sclerosis

There is no clear correlation found between the incidence of sclerosis in the coronary ostial area and the coronary artery itself. There are 14 clear cases of severe coronary sclerosis, seven of which are coronary ostial sclerosis with stenosis complication. On the other hand, the degree of advancement of the atherosclerosis in the ascending aorta and coronary sclerosis show a positive correlation (Fig. 7).

Fig. 7. Relationship between degree of coronary and aortic sclerosis.

B) The microscopic study of the coronary ostium

1) Specific structure of the coronary ostium

Macroscopic examination of the coronary ostium revealed a well-defined dimple,

Fig. 8. Microscopic view of the coronary ostium. Specific structure is noticed. (longitudinal section, EvG stain, 12x.)

Fig. 9. Schematic presentation of the specific structure around the coronary ostium.

which can be anticipated as if it is a specific structure. This portion was cut into series for further detailed microscopic examination. Normal coronary ostia possess a uniform arrangement in the smooth muscle on the media of the aorta and the coronary artery. The particular arrangement produces a distinct border, and is comprised of a longitudinal muscle, which spreads out in the inner layer, and a circular muscle, which surrounds the outer layer (Fig. 8). The ratio between these two muscles differs in the upper and lower portions of the ostium. Additionally, a spiral twist can be anticipated in the smooth muscle arrangement (Fig. 9).

2) Atherosclerotic changes of the coronary ostium and aging

The ostial wall fibrosis was examined and classified into four degrees (0), (+), (##), and (###), and the relationship with aging was examined. There are cases of mild fibrosis in 60% of the patients under 30 years old. With aging, the degree of fibrosis increases and among the patients over 71, 30% show severe fibrosis with loss of smooth muscle and replacement by collagen fibers. In addition, the calcified atheroma and fibrosis increase as a function of age. Atheromatous degeneration at the age of 50 is 15%. Over 51, it suddenly increases to 67% and was noted in all patients over 71. The rate of calcified atheroma occurrence is

Table 1. Clinicopathological data in coronary sclerotic cases.

C A S E	A G E	S E X	Clinical and pathological diag.	Heart weight (g)	Grade of atherosclerosis					
					Aorta	Coronary ostium		Coronary stem		Coro- nary sclerosis
						R	L	R	L	
1	75	M	Rupture of abdominal aneurysm Subendocardial infarct	340	D 0163	Occluded	Severe	Occluded	#	12
2	74	M	Parotid cancer Subendocardial infarct	350	D 0154	Severe	Occluded	+	+	3
3	51	M	Cor pulmonale	440	B 2350	Moderate	Severe	+	#	6
4	70	M	Gastric cancer Subendocardial infarct	290	C 0280	Moderate	Mild	#	Occluded 2cm from ostium	10
5	63	M	Myocardial infarct (anteroseptal)	530	C 2260	Moderate	Mild	#	Occluded 1.5cm from ostium	12
6	68	M	Myocardial infarct (anteroseptal)	350	B 7300	Moderate	Mild	#	Occluded	13
7	74	M	Gastric cancer Subendocardial scar	550	B 2440	Mild	Mild	+	Occluded	11
8	72	M	Myocardial infarct (anteroseptal)	470	B 2530	Mild	Mild	+	Occluded	9
9	63	M	Myocardial infarct (inferior)	440	D 1261	Severe	Severe	Occluded	#	13
10	83	M	Myocardial infarct (anteroseptal)	360	D 0253	Moderate	Severe	#	Occluded	10

much lower—about 20% between 50 and 70 and 50% over 71.

C) The clinicopathological study of ostial atherosclerotic narrowing

Within the various age groups, patients with pathologically atherosclerotic ostia were selected and the significance of this condition was studied. Of the 70 patients, seven, or 10%, show ostial narrowing only on the right side; three, or 4.3%, only on the left; and four, or 5.7%, on both sides. Of these cases, 12 are male and two are female. The age range is from 44 to 75, the average being 65.

A comparison study was made on the 56 cases that were free of ostial narrowing and sclerosis. Among these, indications of advanced aortic sclerosis are found in nine cases, or 16%, as compared to five, or 35.7%, of the 14 pathologic cases. And indications of coronary sclerosis are found in six cases, or 10.7%, compared with 50% of the pathologic cases. This clearly shows that

in cases of ostial stenosis, atherosclerosis is severe in the ascending aorta and the coronary artery.

In the pathological research, there are nine cases of myocardial infarction of which four have coronary ostial stenosis. Four cases, or 30.7%, of the 14 patients with ostial stenosis, reveal myocardial infarction, a high rate compared with five, or 8.9%, among the 56 with normal ostia.

Next, the coronary ostia of the cases of severe atherosclerosis of the aorta and the coronary artery were studied. There are 27 cases of advanced sclerosis out of the 70, of which 22 cases are male and five are female. By age, one is in the 40-year-old group, four in the 50-year-old group, nine in the 60-year-old group, 11 in the 70-year-old group and two in the 80-year-old group. Sixty percent had a past history of hypertension, 44% of hypercholesteremia and 73% of terminal azotemia.

As mentioned previously, the right ostium is usually a double circular shape

and the left mainly comet shaped. But among the patients suffering from severe coronary sclerosis, seven cases of flat shaped ostia on both the left and right, tending to hide the funnel-shaped structure, are found. The incidence of this overhang formation is overwhelmingly high on the right—61.5 %, as compared to 15.4% on the left.

In the coronary sclerotic group, 10 cases which had sclerosis and stenosis of the ostium and the main trunk of the coronary artery were selected and clinicopathological study was conducted (table 1). Nine have myocardial infarction and, of those, four reveal coronary ostium occlusion and severe stenosis. There are two cases of complete ostial obstruction, one each on the right and left sides. These are denoted, respectively, Case 1 and Case 2. In Case 1, the change of the coronary artery itself shows severe sclerosis and stenosis, whereas in

Fig. 10. Microscopic view of the coronary ostium. Severe atherosclerotic change is observed at right coronary ostium (longitudinal section, EvG stain, 12x.)

Case 2, the sclerosis of the coronary artery itself is mild. In both cases, there is subendocardial infarction.

Case 1 was chosen as a representative example of coronary ostial stenosis. The patient was a 75-year-old male, director of a company. His medical history showed that he was hospitalized in April 1968 for cerebral thrombosis. The laboratory data at that time were negative to the serologic test for syphilis and showed the presence of hypercholesteremia. An electrocardiogram showed left axis deviation with complete right bundle branch block. In March 1970, he suffered from a sudden severe abdominal pain and died in a state of shock. The cause of death was found to be rupture of the aneurysm of the abdominal aorta. On the coronary ostia, a severe stenosis was apparent. On the upper margin of the right sinus of Valsalva, there was a large calcification and necrosis accompanied by atheromatous plaque. This plaque had completely obstructed the right coronary ostium (Fig. 10). There was severe sclerosis of the coronary artery itself, with the left anterior descending branch and the right coronary artery revealing over 75% stenosis. With the advanced atherosclerosis, subendocardial infarction had occurred, covering nearly the entire left ventricle and scattering to subendocardial third of the myocardium, with parts fused with extensive fibrosis.

DISCUSSION

So far there has been very little research on the coronary ostium^{4,5}. Thus this study was conducted to explore the actual need for basic pathological knowledge of the coronary ostium in the interests of safe and speedy coronary angiography and surgery. The coronary ostium opens at the bottom of the peculiar dimple showing a funnel-shaped structure in the sinus of Valsalva. The funnel-shaped structure is found in various shapes, with the right side being mostly double-circular and the left being mostly comet-shaped. The position where

the shape differs on the two sides is approximately at right angles to the right coronary artery and at a sharp angle to the left coronary artery. This is believed to be caused by the different angles at which the left and right coronary arteries emerge from the aorta. Most of the funnel-shaped structures are located at the sinus of Valsalva and tend to become larger, deeper and more noticeably delineated with aging. But when the coronary sclerosis becomes severe, this structure becomes shallow and flat and the boundary becomes indistinct. Since this structure is evident even in young patients and it becomes deeper and spreads with aging, it can be reasoned that the hemodynamic change was not just caused by the secondary occurrence, but can be anticipated as a specific structure designed to draw blood most efficiently and in large quantities into the coronary artery.

In this connection, it is very interesting that the whorl-shaped structure of the coronary ostium was sketched by Leonardo da Vinci. In our daily life, we usually experience that, when pouring liquid into the small opening of a funnel, it is quicker to do so by making a whirl. Therefore, the authors conducted a systematic study of the funnel-shaped structure of the ostium by making serial section cuts. It is composed of longitudinal muscle tissue running out from the inner layer and circular muscle tissue covering the outer layer. The longitudinal and circular muscular tissue ratio varies between the upper and lower portions of the ostium and the spiral-shaped structure has been indicated. This coincides with the sketch of Leonardo da Vinci, for whose artistic genius and sharp observation the authors have deep respect. The authors plan to make further study in the future on this smooth muscle spiral to discover if it actually makes a blood flow whirl and produces a large quantity of blood to the coronary artery in a short period, in keeping with the physiological requirement.

The overhang phenomenon, caused by

atheroma and fibrosis around the coronary ostium, becomes more apparent, frequent and severe with aging and the development of coronary sclerosis. Its location is at the upper ostial margin on the right side and mostly on the upper right margin on the left. Its occurrence is more frequent on the right side than on the left.

It has been confirmed that the atherosclerosis is most marked in the upper margin on the right and at the right upper margin on the left.

Right ventricular pressure is much lower than that in the left ventricle. The pressure which develops within the thin right ventricular wall is so much lower that blood flow into the right coronary artery continues at a fairly high level during both systole and diastole. Thus, right ventricular contraction does not represent nearly as great an impedance to net coronary flow as the contraction of the left ventricle. It is believed that the left has correlation mainly with diastolic flow. We believe that one of the causes and promoting factors of atherosclerosis is mechanical stimulation and that the longer the duration of the blood flow the severer the sclerosis is. If the hypothetical blood flow on the right ostia is greater than the left statistically, the fact that sclerosis is more severe on the right can be seen as no contradiction. The difference in the location of the atherosclerosis on the left and right ostia is believed to be caused by the difference in the angles between the aortic and coronary arteries on the two sides.

Microscopic examination of the ostia of patients under 30 years old shows that connective tissue growth is already noticeable and that hypertrophy and fragmentation of smooth muscle co-exists. Loss of the ostial smooth muscle is severe compared to other areas and, from the high frequency of ostial atheroma among the elder patients, we can deduce that the ostium performs a special function and that mechanical stress has been added.

With the progress of sclerosis of the aorta, the funnel-shaped structure of the

ostium becomes flat and the border becomes indistinct. Furthermore, the overhang phenomenon appears frequently, especially on the right side, and severe changes are noted. This overhang formation is the result of the dynamic stimulus of the blood flow and becomes, at the same time, an inhibitor of that flow. Of a group of 14 patients with pathologically narrowed ostia, four, or 28.5% suffered from myocardial infarction. This leads to the conclusion that, with regard to the development of myocardial infarction, not only the sclerosis and stenosis of the coronary artery itself, but also ostial stenosis must be taken into account.

Furthermore, among a group of patients found to be suffering from abnormally narrowing ostia and severe atherosclerosis of the aorta and main trunk of the coronary artery, there were nine cases of myocardial infarction, including four of subendocardial infarction.

A case report presented was that of left and right ostial stenosis caused by atherosclerosis. The right ostium was completely obstructed and, even without the presence of syphilis, there was severe sclerosis leading to complete obstruction—an interesting case where ring-form subendocardial infarction had taken place. In the present research, atherosclerosis has been regarded as the cause of stenosis of the coronary ostium. But documented record reports many stenosis caused by syphilitic mesoaortitis⁶⁻¹⁰). There are very few illnesses that can cause ostial stenosis besides aortic sclerosis and syphilis. Among them, however, are the aortitis syndrome¹¹), dissecting aneurysm¹²⁻¹⁶), Marfan syndrome, aortic valvular disease¹⁷) and congenital aortic malformation¹⁸⁻²⁰) all of which must be studied in the future.

In the present study of coronary sclerotic heart disease, changes of the ostium cannot be overlooked. When the stenosis is limited to the coronary ostial area, surgical indication should be high.

In the future, with the increase of coronary bypass surgery, such measures as

thrombectomy, endoarterectomy, ostial overhang removal and ostial reconstructive surgery can be anticipated.

CONCLUSION

A morphological study of the coronary ostium and a clinicopathological study of its stenosis have been conducted on 70 unselected autopsy cases, and the following conclusions have been obtained.

(1) The ostium has a particular well-defined and forms a funnel-shaped structure.

(2) The structure is predominantly a double circular shape on the right and comet-shaped on the left.

(3) This structure reveals a special formation, comprised of a longitudinal muscle, which spreads out in the inner layer, and a circular muscle, which surrounds the outer layer.

(4) The average area of the coronary ostium is 23.5mm² on the left and 16.1mm² on the right.

(5) Including the overhang formation, coronary sclerosis of the ostium appears mainly on the upper margin of the funnel-shaped structure on the right ostium and at the upper right margin of the left.

(6) Atherosclerosis tends to be more severe in the right ostium than the left.

(7) Stenosis caused by ostial atherosclerosis on the right side occurred in 7 out of the 70 cases, or 10%, on the left side in three cases, or 4.3%; and among them on both sides in four cases, or 5.7%. Among the 14 patients with pathologic ostial narrowing, there were four, or 28.5%, with myocardial infarction, a high rate compared to five, or 8.9%, with infarction among the 56 with normal ostia.

(8) In ischemic heart diseases, along with changes in the coronary arteries themselves, changes in the ostia of these arteries should be given serious attention.

ACKNOWLEDGMENTS: The authors wish to express their appreciation to Prof Y. Fukuda, Prof K. Hashimoto and all members of the Dept. of Pathology, Juntendo University for their donation of materials, their advice and encouragement.

REFERENCES

- 1) Eshe S: Leonardo da Vinci. Das anatomische Werk. Holbein-Verlag, Basal, 1954.
- 2) Gore I, Tejada C: The quantitative appraisal of atherosclerosis. *Atherosclerosis* 33: 875, 1957.
- 3) Classification of atherosclerotic lesions. (report of a study group) *Wld Hlth Org Techn Rep Ser* 143: 1958.
- 4) Vlodaver Z, et al: Pathology of angina pectoris. *Circulation* 46: 1048, 1972.
- 5) Enos WF, et al: Arteriosclerosis of the aortic sinuses. *Amer J Clin Path* 39: 506, 1963.
- 6) Scharfman WB, et al: Myocardial infarction due to syphilitic coronary ostial stenosis. *Amer Heart J* 40: 603, 1950.
- 7) Michaud P, et al: Syphilitic ostial coronaritis. *J. of Cardiovasc. Surg* 12: 254, 1971.
- 8) Bech W, et al: Syphilitic obstruction of coronary ostia successfully treated by endoarterectomy. *Brit Heart J* 27: 911, 1965.
- 9) Connolly JE, et al: Proximal coronary-artery obstruction. Its etiology and treatment by transaortic endoarterectomy. *New Engl. J of Med* 271: 213, 1964.
- 10) Leary T, Wearn JT: Two cases of complete occlusion of both coronary orifices. *Amer Heart J* 5: 412, 1930.
- 11) Barker NW, Edwards JE: Primary arteritis of the aortic arch. *Circulation* 11: 486, 1955.
- 12) Wainwright CW: Dissecting aneurysm producing coronary occlusion by dissecting of the coronary artery. *Bull Johns Hopkins Hospit* 75: 81, 1944.
- 13) Bayley RH, Monet LA: Acute local ventricular ischemia or impending infarction caused by dissecting aneurysm. *Amer Heart J* 25: 262, 1943.
- 14) Weiss S: Dissecting aneurysm of the aorta: 2 cases with unusual features. *New Engl. J Med* 218: 512, 1938.
- 15) Lindsay J, Hurst JW: Clinical features and prognosis in dissecting aneurysm of the aorta. *Circulation* 35: 880, 1967.
- 16) Abe M, et al: An autopsied case of the dissecting aortic aneurysm with myocardial infarction. *Int Med* 31: 330, 1973. (in Japanese)
- 17) Waxman MB, Behar VS: Fusion of the left aortic cusp to the aortic wall with occlusion of left coronary ostium, and aortic stenosis and insufficiency. *Circulation* 41: 5, 1970.
- 18) Eliot RS, et al: Congenital aneurysm of the left aortic sinus.—A rare lesion and a rare cause of coronary insufficiency. *Circulation*, 28: 951, 1963.
- 19) Neufeld HN, et al: Hypoplasia of ascending aorta: An unusual form of supravalvular aortic stenosis with special reference to localized coronary arterial hypertension. *Amer J Cardiol* 10: 746, 1962.
- 20) Kreel I, et al: Supra-valvular stenosis of the aorta. *Ann Surg* 149: 519, 1959.