Supravalvular Aortic Stenosis
Clinical, Hemodynamic and Pathologic Observations

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In 3 patients obstruction to left ventricular outflow was shown to be due to a localized narrowing of the aortic root at the point of insertion of the aortic leaflets. The site of obstruction was localized by left heart catheterization and selective angiography. The pathologic findings in 2 patients are described and the problem of the surgical management of this unusual form of aortic stenosis is discussed.

Previous reports have dealt in detail with the clinical and hemodynamic findings in patients with obstruction to left ventricular outflow caused by congenital valvular or subvalvular aortic stenosis. More recently it has been shown that a systolic pressure gradient between the left ventricle and aorta may also result from functional obstruction in the outflow tract of the ventricle secondary to massive left ventricular hypertrophy. Among the group of patients with congenital aortic stenosis who have been studied at the National Heart Institute, 3 have been shown to have obstruction to outflow caused by a constriction in the aorta itself immediately distal to the valve. In the present report the results of diagnostic studies in these 3 patients are described and the pathologic findings in 2 of them are presented.

Clinical Summaries

1. J. R., an 8-year-old girl was, first admitted to the National Heart Institute in November 1956, known to have a heart murmur since birth. Her growth and development have been markedly retarded (her weight was below the third percentile on a standard grid) and she had been subject to frequent respiratory infections. The heart was enlarged and the point of maximal impulse was the sixth intercostal space in the midclavicular line. A systolic thrill was palpable at the base of the heart and over the carotid arteries. The second heart sound in the pulmonary area was accentuated and split. A grade-IV/VI systolic ejection murmur was heard best along the right sternal border and was transmitted to the neck. The rhythm was regular. The blood pressure in the right arm was 106/16 and in the left arm 112/0 mm. Hg. The electrocardiogram revealed sinus tachycardia, left ventricular hypertrophy, right axis deviation, and P waves suggestive of right atrial enlargement. Fluoroscopic and radiographic examinations demonstrated enlargement of both ventricles. The aorta was not dilated. At right heart catheterization the pulmonary artery pressure was 70/24 mm. Hg, and the catheter was passed through a patent ductus into the descending aorta. A retrograde thoracic aortogram was carried out (fig. 1). The sinuses of Valsalva appeared normal, and there was an apparent constriction of the aortic root immediately above them. Some left ventricular opacification indicated mild coexisting aortic regurgitation. The aorta itself was smaller than normal. The patent ductus was again demonstrated.

In February 1957 the patent ductus was closed through a posterolateral thoracotomy. Although the aortic root could not be inspected, a pressure gradient between the left ventricle and aorta following closure of the ductus was confirmed by simultaneous pressure measurements. The left ventricular pressure at this time was 194/10 mm. Hg and the peak systolic gradient was 81 mm. Hg.

In the 2 years following this operation, the child experienced no further serious respiratory infections but still failed to grow and gain weight. She began to complain of fatigability and became dizzy with strenuous exercise on several occasions. She was readmitted to the Institute in July 1958 for re-evaluation and aortic valvulotomy.

The physical findings on this occasion revealed a blood pressure of 96/80. The classic thrill and murmur of aortic stenosis were present, and the
Fig. 1. Lateral view of the thoracic aortogram (top) and its schematic interpretation (bottom) obtained in patient J.R. The supravalvular area of constriction is indicated.

Fig. 2. Drawing of the heart and aorta of patient J.R. The constriction at the upper margins of the sinuses of Valsalva and the valve deformity are shown. The enclosed area is shown microscopically in figure 3.

The second heart sound in the aortic area was diminished in intensity. Another right heart catheterization was performed; the pulmonary artery pressure had fallen to 45/8 mm. Hg, and absence of a left-to-right shunt was shown by a pulmonary artery nitrous oxide test of 1 per cent. Percutaneous puncture of the left ventricle was carried out under general anesthesia. The peak systolic gradient between the left ventricle and femoral artery was 52 mm. Hg. Operation for relief of the supravalvular obstruction was recommended but on the morning of the scheduled procedure the child had cardiac arrest on the ward and attempts at resuscitation were unsuccessful.

Pathologic Description. The heart weighed 200 Gm. and both ventricles were hypertrophied. The aorta and pulmonary artery were in normal position and there were no abnormalities of the chambers or septa. The deformities of the aortic valve and ascending aorta which produced stenosis are illustrated in figure 2. There were 3 normal-sized but thickened valve leaflets. A fibrous band originated at the center of the free edge of each leaflet and inserted into the thickened aortic intimal plica at the upper margin of the sinuses of Valsalva. The resulting shelf-like thickening narrowed the aortic orifice to a diameter of 5 mm.
Above the stenosis the aorta was 10 mm. in diameter.

The microscopic appearance of a vertical section through the left coronary leaflet is shown in figure 3. There was considerable fibrous thickening of the upper portion of the leaflet. The nodule of Arantii was absent and the sinus of Valsalva was bridged by a band of dense connective tissue that inserted into the intima of the thickened aorta at the upper margin of the sinus. An area of subendothelial fibrosis in the base of the sinus resembled a "jet" lesion. There was moderate coronary arteriosclerosis.

2. E. B., an 18-year-old boy in whom a murmur had first been noted immediately after birth. At the age of 7 years he developed subacute bacterial endocarditis and pneumococcus type IV was cultured from his blood. The infection was cured by the administration of penicillin and he had no symptoms until age 17, when he experienced sudden severe precordial pain and was hospitalized for 3 days. A chest x-ray is said to have shown a calcified aneurysm of the ascending aorta. The patient had no further chest pain or limitation of activity and was asymptomatic at the time of his first admission to the National Heart Institute a year later.

Physical examination at this time revealed normal development and was unremarkable except for the cardiovascular system. The heart was enlarged and the point of maximal impulse was in the sixth left intercostal space outside the midclavicular line. A left ventricular lift was palpable at the apex and a systolic thrill was felt to the right of the sternum and over the carotid vessels. The aortic second sound was decreased and a grade-V/VI harsh systolic ejection murmur was audible over the entire precordium; it was of maximal intensity in the second and third right intercostal spaces. Blood pressure in the right arm was 110/70 mm. Hg and in the left arm 90/60. The peripheral pulses were palpable and the rhythm was regular.

The electrocardiogram revealed left bundle-branch block and there were occasional premature ventricular contractions. Fluoroscopic and radiographic examinations of the chest demonstrated appreciable enlargement of the left ventricle, and a calcified mass was seen to the right of the aortic arch. Right heart catheterization revealed a pulmonary artery pressure of 20/8 mm. Hg and the pulmonary artery nitrous oxide test was negative (15 per cent). The cardiac output at rest was 2.26 L per minute per M.² and on exercise rose to 4.26 L per minute per M.² Left heart catheterization was carried out by the transbrachial method.⁵ The mean left atrial pressure was 12 mm. Hg and its contour was normal. The left ven-

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**Fig. 3.** Photomicrograph of section through the left coronary leaflet of the aortic valve in patient J.R. Orientation as illustrated in figure 2. PA, pulmonary artery; PV, pulmonary valve; LV, left ventricular cavity; AA, ascending aorta; RA, root of aorta; AC, left coronary aortic leaflet; SV, sinus of Valsalva; FB, fibrous band attaching leaflet to aortic wall; J, jet lesion in base of sinus; LCA, left anterior descending coronary artery. Orcein-hematoxylin, × 6.5.

**Fig. 4.** Pressure recording made in patient E.B. as a catheter was withdrawn from the left ventricle (LV) into the aortic arch. The intraaortic pressure gradient is shown. The femoral artery pressure (FA) is also indicated.

tricular pressure was 300/15 mm. Hg and the right radial artery pressure, measured simultaneously, was 155/86 mm. Hg, resulting in a peak systolic gradient of 145 mm. Hg. The cardiac
Because of the difference in blood pressure between the right and left arms, the left ventricle and aorta were catheterized from the right radial artery. On this occasion, under general anesthesia, the left ventricular pressure was 180/12 mm. Hg and, as the catheter was withdrawn, progressively lower aortic pressures were recorded (fig. 4). Immediately distal to the valve it was 180/75 mm. Hg, and in the aortic arch the pressure was 120/75 mm. Hg. The femoral artery pressure was 110/75. The pressure tracings were considered diagnostic of supravalvular aortic stenosis, and to characterize the lesion further the catheter was replaced in the left ventricle and a selective angiocardiogram carried out: 50 ml of 70 per cent Urokon were injected with a Gidlund syringe and anteroposterior and lateral films were simultaneously exposed at the rate of 6 per second (figs. 5 and 6). These demonstrated the left ventricle to be large and thick-walled. The aortic leaflets were normal in position and mobility. Immediately above the valve there was an apparently discrete narrowing of the aortic root. The sinuses of Valsalva were somewhat enlarged and all branches of both coronary arteries were enormously dilated and tortuous. The ascending aorta itself was small and a saccular aneurysm was seen to fill from the aorta near the origin of the innominate artery. The lateral views (fig. 6) also demonstrated some reduction in the lumen of the transverse portion of the aortic arch.

Operation for relief of the supraventricular obstruction was recommended but deferred for 1 year at the patient’s request. He was readmitted in July 1958 at which time physical and laboratory findings were unchanged. At operation (July 17, 1958) the aorta was found to be small and there was an intense systolic thrill palpable within it. The huge coronary arteries were again noted. The aortic root was dissected and, after the institution of cardiopulmonary bypass and elective cardiac arrest, the aorta was widely opened. The site of stenosis was a thick fibrous ridge and local resection was deemed impossible. The lumen of the aorta at the site of constriction was enlarged by the insertion of a diamond-shaped prosthesis of compressed polyvinyl sponge. After 67 minutes coronary perfusion was restored but an effective heart beat never resulted.

Pathologic Description. The heart was greatly enlarged, weighing 850 Gm., and there was a 2.5-cm. calcified saccular aneurysm arising from the ascending aorta near the origin of the innominate artery. The entire aorta was hypoplastic and was only 12 mm. in outside diameter. The coronary arteries were enormously dilated and tortuous; the right was 10 mm. in diameter and the left 7 mm.
SUPRAVALVULAR AORTIC STENOSIS

In figure 7 the aorta has been opened to show the stenotic segment, 18 mm. long, immediately above the upper margin of the aortic valve. The polyvinyl prosthesis lay in the position shown and the diameter of this stenotic segment, including the prosthesis, was only 9 mm. The aortic valve leaflets were thin and sacular and their free margins at the commissures were elongated so that the margins of the leaflets lay 4 mm. below the orifices of the coronary arteries.

Just above the orifice of the sacular aneurysm was a healed dissecting aneurysm that re-entered the aorta just beyond the origin of the left subclavian artery.

Histologic sections of the aorta revealed degeneration and fibrosis of the media. These changes were particularly pronounced in the thickened stenotic segment of the ascending aorta (fig. 8).

3. J. J., a 7-year-old boy was admitted to the National Heart Institute in August 1958. A murmur had been first noted shortly after his birth. He had been asymptomatic except for slight fatigability. The child exhibited normal development and the significant physical findings were limited to the cardiovascular system. The blood pressure was 94/70, the peripheral pulses were normal. The heart was not enlarged but a ventricular lift was palpable at the apex. There was a coarse systolic thrill over the base of the heart which was also felt in the suprasternal notch and over the carotid arteries. A grade-V/VI ejection-type murmur was maximal in the second and third right intercostal spaces and was referred to the neck. The second heart sound was inaudible at the aortic area.

The electrocardiogram demonstrated left ventricular hypertrophy, and this finding was confirmed by the fluoroscopic and radiographic appearance of the heart. Poststenotic dilatation of the aorta was not apparent. At right heart catheterization the pulmonary artery pressure was 20/6 mm. Hg and the pulmonary artery nitrous oxide index was 3 per cent. Percutaneous puncture of the left ventricle was performed and the left ventricular pressure was 170/5 mm. Hg. The femoral arterial pressure was 110/65 mm. Hg and the peak systolic gradient was 80 mm. Hg (general anesthesia).

These findings were confirmatory of congenital aortic stenosis and operation was carried out in October 1958. At thoracotomy the entire ascending aorta was small and an intense systolic thrill was palpable within it. All the visible coronary arteries were greatly enlarged and tortuous. When the aortic root was dissected, a constriction immediately distal to the sinuses of Valsalva was apparent (fig. 9). No thrill was felt in the sinuses themselves, which were of normal size. A cathe-

![Fig. 6. Lateral view of the left ventricular selective angiocardiogram (top) and its interpretation (bottom) in patient E.B. The supravalvular stenosis, dilated coronary arteries, and the aortic aneurysm are seen. The small size of the aorta itself is also well demonstrated.](http://circ.ahajournals.org/)
FIG. 7. Postmortem appearance of the heart and aorta of patient E.B. The stenotic segment of aorta and the prosthesis employed to enlarge the area are shown. The saccular aneurysm of the aorta and the dissection associated with it are also indicated.

ter was passed from the apex of the left ventricle into the aorta and the withdrawal tracing proved the presence of obstruction immediately distal to the valve (fig. 10). An attempt at surgical correction of the lesion was deemed inadvisable. The child remains essentially asymptomatic.

DISCUSSION
Supravalvular aortic stenosis has been described only rarely but in the recent report by Denie and Verheugt9 a review of cases previously described is included. The most common anatomic lesion is apparently a shelf-like thickening and hypertrophy of the plica at the upper margin of the sinuses of Valsalva. This type of stenosis may be associated with a valvular deformity as in patient J.R. The fibrous bands that extended from the free margin of each aortic leaflet to the thickened plica were in this instance apparently responsible for associated aortic regurgitation. The morphology of the valve deformity in patient J.R. suggests that the hollowing of the endocardial cushions was defectively performed and that the hypertrophied plica may have been similarly derived. In the patient reported by Denie9 the free margin of the left coronary leaflet was fused to the aortic wall. The operative appearance of the lesion of patient J.J. suggested that it was of a similar type.

The anatomic lesion of patient E.B. is probably not embryologically similar to the stenosis described above. The stenotic segment was relatively long and was associated with hypoplasia of the aorta as well as degeneration and fibrosis of the aortic media. The history of endocarditis suggests this as an etiologic agent although the infection could have and probably did originate on a previously existing congenital stenosis. The fact that the entire aorta was hypoplastic in this, as well as the other patients, would substantiate congenital narrowing as the basic lesion.

A third type of lesion that may produce supravalvular stenosis was described by
SUPRAVALVULAR AORTIC STENOSIS

Fig. 9. Operative appearance of the heart and aorta of patient J.J. The characteristic hypoplasia of the aorta, and dilated coronary arteries are well demonstrated. The site of supravalvular obstruction is indicated.

Cheu, Fiese, and Hatayama.10 This patient had a crescent-shaped fibrous membrane that encircled three fourths of the circumference of the lumen of the aorta and projected 1.2 cm. into the lumen. Two normal aortic valve cusps were attached to the membrane. Anomalous supravalvular aortic bands have been described and are included in the tabulation of Denie and Verheugt.1 In spite of their speculative interest or possible embryologic relationship to anomalous valve development, clinical disease has not been evident in reported patients and the lesion has generally been an incidental autopsy finding.

On clinical examination the only finding that may serve to suggest the diagnosis of supravalvular aortic stenosis is the absence of poststenotic dilatation of the aorta. Since the aorta may not be dilated when subvalvular or functional stenosis exists,2,3 the presence of supravalvular obstruction can be proved only by left heart catheterization or contrast radiography. The demonstration of a systolic pressure gradient within the aortic root clearly localizes the site of obstruction to a point distal to the valve (figs. 4 and 10). Left ventricular selective angiography and aortography proved the presence of the lesion in the 2 patients in whom contrast studies were carried out. The mere demonstration of a systolic pressure difference between the left ventricle and aorta does not localize the obstruction. Complete left heart catheterization is therefore necessary in the precise preoperative evaluation of any patient with congenital aortic stenosis.

Supravalvular aortic stenosis would seem to carry with it the relatively grave prognosis associated with the more common forms of obstruction to left ventricular outflow. Although the coronary arteries originate below the stenosis and are subjected to an abnormally high perfusion pressure, the additional coronary flow provided apparently does not compensate for the increased burden imposed upon the left ventricle. When the leaflets are fused to the aorta, the entrances to the sinuses of Valsalva may be obstructed and compromise coronary filling.

The method of surgical treatment employed in patient E.B. and contemplated in patient J.R. was suggested by Dr. John W. Kirklin.11 He emphasized that excision of the obstructing ridge would necessitate severance of the attachments of the aortic leaflets and would certainly result in gross aortic regurgitation. The accuracy of this observation is shown by the relationships of the leaflets to the obstruction in figures 2 and 7. Kirklin successfully enlarged the diameter of the aortic root by the insertion of a diamond-shaped polyvinyl patch in a patient in whom the anatomic lesion was similar to those described. A significant reduction in the intraventricular pressure gradient was achieved and it would seem that this method of operative repair will find increasing application.
SUMMARY

The clinical and hemodynamic findings in 3 patients with supravalvular aortic stenosis are described. The diagnosis was established by left heart catheterization and selective angiography. Two patients died, one following an unsuccessful attempt at surgical correction of the lesion. Pathologic findings in these patients indicate that the stenosis, which occurs at the site of insertion of the aortic leaflets, is of congenital origin. The differentiation of this lesion from the more common forms of aortic stenosis and the problem of its surgical management are described.

SUMMARIO IN INTERLINGUA

Es describite le constatationes clinic e hemodynamic in 3 patientes con stenosis aortic supravalvular. Le diagnose eseva establite per catheterismo sinistro-cardiac e angiographia selective. Duo del patientes moriva, le un post le van essayo de corriger le lesion per medios chirurgic. Le constataiones pathologic in iste patientes indica que le stenosis, que occurre al sito del insertion del cuspides aortic, es de origine congenite. Le differentiation de iste lesion ab le formas plus commun de stenosis aortic e le problema de su tractamento chirurgic es describite.

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Circulation. 1959;20:1003-1010
doi: 10.1161/01.CIR.20.6.1003
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/20/6/1003

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