

Regression of valvular pulmonary stenosis¹

Richard D. Lueker, John H. K. Vogel, and S. Gilbert Blount, Jr.

From the Cardiovascular Laboratory, Division of Cardiology, Department of Medicine, University of Colorado Medical Center, Denver, Colorado 80220, U.S.A.

Eight patients with mild to moderate valvular pulmonary stenosis underwent serial physiological studies before surgical intervention. Average pulmonary valve area at the initial study was 0.59 cm.² and at the second study (average 7.8 years later) was 1.09 cm.², resulting in an average increase of 0.49 cm.² ($p > 0.05$).

In normal subjects during early years the pulmonary valve area increases linearly with age and with increasing body surface area. Though patients with valvular pulmonary stenosis have smaller valve orifices, they also show an increase in valve size with increasing age and with increasing body growth. The greatest increase in valve area was observed in 4 patients (all under age 6) in whom body surface area increased more than 70 per cent.

Though valvular pulmonary stenosis (VPS) constitutes a substantial segment of congenital heart disease, little is known about the natural history of this lesion, particularly in patients with mild to moderate stenosis. Published work has supported opposing views. While some reports have suggested that mild valvular pulmonary stenosis does not progress (Tinker *et al.*, 1965; Barritt, 1954; Wood, 1956; Campbell and Missen, 1959; Nadas, 1963), others have stated that mild to moderate valvular pulmonary stenosis may increase in severity with age (Engle, 1957; Sobin *et al.*, 1954; Campbell, 1960; Engle, Ito, and Goldberg, 1964).

Fabricius (1959) reported serial catheterization studies in 12 patients with valvular pulmonary stenosis. In 3 patients, right ventricular pressure increased by more than 20 per cent, whereas in the remaining 9 patients right ventricular pressure increased by less than 20 per cent. Pulmonary valve areas were not calculated. In 3 patients studied by serial catheterization, Tinker *et al.* (1965) reported an increased gradient in one case and decreased gradients in the other two. Pulmonary valve areas were not calculated. Moller and Adams (1965) performed serial catheterizations after an average interval of 5 years in patients with mild valvular pulmonary stenosis and showed that the pulmonary valve area had increased in 16 out of 17 patients.

In an attempt to clarify the conflicting reports regarding this congenital abnormality,

Received 26 April 1970.

¹ Supported in part by the U.S.P.H.S. Grant.

serial studies were performed in 8 subjects with mild to moderate valvular pulmonary stenosis to determine how valve area changes with time. These changes are related to normal pulmonary valve growth.

Materials and methods

Eight patients with mild to moderate valvular pulmonary stenosis (5 male, 3 female) underwent serial cardiac evaluation without surgical intervention. Routine clinical studies included x-rays and electrocardiograms. Right heart catheterizations were performed in the usual manner and hydrogen curves were obtained in the pulmonary artery to exclude any coexistent left-to-right shunt (Vogel, Grover, and Blount, 1962). Cardiac output was determined by the Fick method, and pulmonary valve area and pulmonary valve index were calculated using the method of Gorlin (1966). Normal valve areas were calculated from valve circumferences reported by Schulz and Giordano (1962). The valve index was determined from heights and weights obtained from the Children's Research Council.

At the time of the initial study the patients ranged in age from 2 months to 28 years (average 10 years). The average interval between studies was 7.8 years (range 3.5 to 10 years).

Results

Pulmonary valve area The average pulmonary valve area at the time of the initial study was 0.59 cm.² (range 0.13 to 1.45) and at the time of the second study 1.09 cm.² (range 0.55-2.12): an average increase of 0.49 cm.² \pm 0.21 ($p > 0.05$) (Table).

In 7 of the 8 patients, pulmonary valve

TABLE Data on eight patients with valvular pulmonary stenosis

Case No.	Ages (yr.) at		Interval (yr.)	Change in pulm. valve area		Change in pulm. valve index		Change in body surface area		Pulmonary valve gradient		
	1st study	2nd study		cm. ²	Per cent	Index	Per cent	m. ²	Per cent	1st study	2nd study	Change
1	3	13	10	0.50-1.38 (+0.88)	+176	0.83-0.95 (+0.12)	+14.5	0.60-1.52 (+0.92)	+153	31	18	-13
2	3	13	10	0.29-2.12 (+1.83)	+630	0.47-1.29 (+0.82)	+174	0.61-1.65 (+1.04)	+171	50	32	-18
3	6	14	8	0.34-0.56 (+0.22)	+65	0.46-0.45 (-0.01)	-2	0.74-1.27 (+0.53)	+72	37	24	-13
4	5½	9	3½	0.82-0.78 (-0.04)	-5	1.12-0.62 (+0.50)	-45	0.86-1.25 (+0.39)	+45	42 and 35	51	+9 or +16
5	11	21	10	1.45-1.81 (+0.36)	+25	1.05-0.92 (-0.13)	-12	1.38-1.93 (+0.55)	+40	17	17	—
6	13	19	6	0.43-0.55 (+0.12)	+28	0.35-0.38 (+0.03)	+9	1.22-1.44 (+0.22)	+19	85	87	+2
7	28	36	8	0.77-0.93 (+0.16)	+21	0.39-0.46 (-0.07)	+18	1.96-2.00 (+0.04)	+2	26	25	-1
8	2/12	7	7	0.13-0.56 (+0.43)	+330	0.55-0.62 (+0.07)	+12.7	0.24-0.89 (+0.65)	+270	40	23	-17

area increased by 21 per cent to 630 per cent, with an average increase of 150 per cent (Table). The pulmonary valve area increases linearly with age in normal subjects, and in the majority of our subjects with valvular pulmonary stenosis the pulmonary valve area likewise increased with age (Fig. 1).

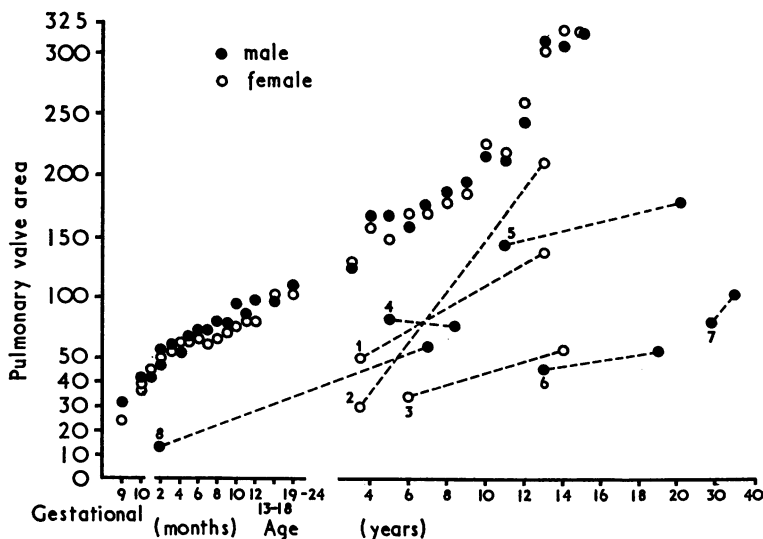
Pulmonary valve index Body surface area increased in all patients. In 4 patients it increased more than 70 per cent between studies, while in the other 4 patients it increased less than 50 per cent. Of the former group, the pulmonary valve area showed the greatest increase (65% to 630% increase), while in the latter group, the pulmonary valve area increased less than 30 per cent (Fig. 2). The average pulmonary valve index at the time of the initial study was 0.65 cm.²/m.² (range 0.35-1.12), and it subsequently increased to an average value of 0.71 cm.²/m.² (range 0.38-1.29). Of the 8 patients, 5 showed increases in the pulmonary valve index, ranging from 0.07 to 0.82 cm.²/m.². The pulmonary valve index decreased in 2 patients by 0.50 and 0.13 cm.²/m.², respectively, and was unchanged in one patient. Pulmonary valve index showed the most conspicuous increase in those patients having the most pronounced increase in body surface area. In those patients in whom body surface area increased less than 50 per cent, the pulmonary valve index decreased in 2 (18% and 19%, respectively).

Pulmonary valve gradient In 4 patients the pulmonary valve gradient decreased 13 to 18 mm. Hg between the first and second

study; in 3 the gradient was unchanged and in one there was an increase (9 mm. Hg). The 4 patients with a decrease in gradient showed the most obvious increase in valve area between the initial and final catheterizations as well as the greatest increase in body surface area.

Electrocardiogram The electrocardiogram was not particularly sensitive, either in

FIG. 1 Relation of pulmonary valve area to age in normal subjects and in patients with pulmonary valvular stenosis. Pulmonary valve area (mm.²) increases with age in normal subjects (upper) and in patients with pulmonary stenosis (lower).



the diagnosis of right ventricular hypertrophy or in indicating change in right ventricular pressure. In those patients with right ventricular systolic pressures ranging from 35–50 mm. Hg, electrocardiographic evidence of right ventricular hypertrophy was definite in 1, questionable in 2, and lacking in the remaining 5 cases. When right ventricular systolic pressure ranged between 50 and 75 mm. Hg, the electrocardiogram suggested right ventricular hypertrophy in 3 instances, but not in the remaining 3 cases. In the 2 cases with right ventricular pressure greater than 75 mm. Hg, the cardiogram showed questionable evidence of right ventricular hypertrophy in one case, and was normal in the other.

Furthermore, the cardiogram was not particularly sensitive in indicating changes in right ventricular pressure. In 1 patient (Case 2) the right ventricular pressure fell 18 mm. Hg between studies and the cardiogram indicated a decrease in right ventricular hypertrophy though the axis remained at 120° . In the remaining 2 patients (Cases 1 and 3) the right ventricular pressure fell 15 and 13 mm. Hg, respectively, but the cardiogram did not indicate any change nor was right ventricular enlargement suggested in either instance. In one patient (Case 8) the electrocardiogram at age 13 showed right ventricular hypertrophy at the first study; 6 years later, the cardiogram had reverted to normal in spite of the persistence of right ventricular pressures in excess of 100 mm. Hg.

Clinical features Physical examination and routine postero-anterior and lateral chest films were characteristic of valvular pulmonary stenosis in all cases. Three patients had mild to moderate symptoms of dyspnoea on exertion, and 2 of the 3 had some increase in symptoms during the year before their final catheterization and operation. Case 7, the oldest patient in our study, was operated on because of increasing symptoms. Peak right ventricular systolic pressure had decreased slightly during the intervening years, but the transvalvular gradient had not changed. Case 8 had persistent increases in right ventricular pressure (100 mm. Hg systolic) and the pulmonary valvular gradient remained raised (87 mm. Hg). After operation, right ventricular pressure returned to normal and only a 5 mm. Hg gradient was present across the pulmonary valve. Case 4 showed no clinical change, but was operated on because of a persistent and significant pulmonary valve gradient.

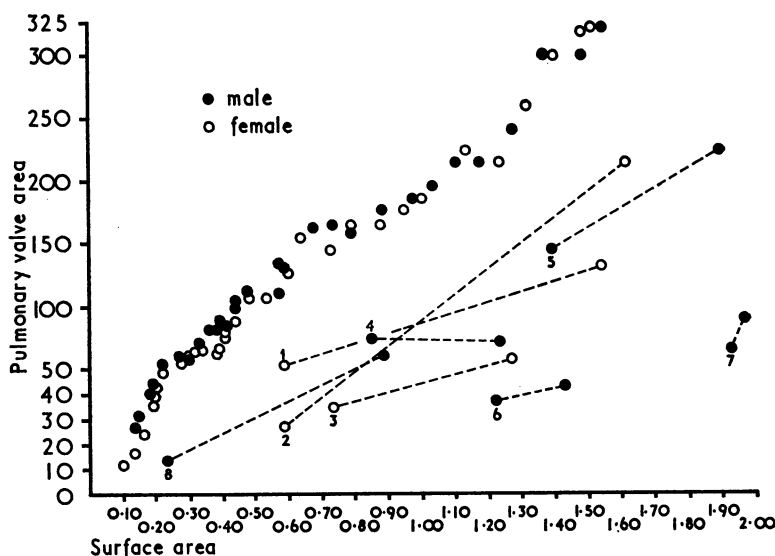


FIG. 2 *Relation of pulmonary valve area to body surface area in normal subjects and in patients with pulmonary valvular stenosis. There is a linear relation between body surface area (m^2) and pulmonary valve area in normal subjects and in patients with pulmonary stenosis.*

Discussion

The fate of patients with mild to moderate valvular pulmonary stenosis is not clearly known, as clinical studies are incomplete. Various investigators have followed the course of such patients using clinical information and cardiographic criteria as determinants of right ventricular pressure and severity of the stenosis. While some have considered the cardiogram to be reliable in this regard, others have not found this to be true.

Hugenholtz, Hauck, and Nadas (1963) have stated that the most reliable single parameter in the evaluation of valvular pulmonary stenosis is an estimate of valve size. Though pressure gradients are of value, they are obviously variable as they depend on cardiac output. Most authors agree that the degree of stenosis is not the only factor in the eventual fate of such patients, i.e. myocardial factors are of considerable importance. The continued deterioration of some patients following relief of obstruction has been attributed to such myocardial factors, i.e. fibrosis, etc. (McIntosh and Cohen, 1963). The abnormal exercise response frequently seen in such patients after operation may also be related to this problem.

Our study supports the observations of Moller and Adams (1965) which showed that the pulmonary valve area increased with age in children and young adolescents with moderate valvular pulmonary stenosis. Gasul, Arcilla, and Lev (1966) speculated that the pulmonary valve area usually increased; for if stenotic valves did not enlarge with increasing growth and stroke volume, critical stenosis and congestive failure would be seen with much greater frequency.

Observations from necropsy material indicate a linear increase in pulmonary valve area with age. Though patients with valvular pulmonary stenosis have smaller valve orifices, it is evident from this study that valve size increases with age and body growth. The greatest increases in pulmonary valve area were seen during the phase of most rapid growth. Such observations were most remarkable in 4 patients, all under 6 years of age at the time of the initial study, in whom body surface area increased more than 150 per cent. The greatest increases in pulmonary valve area were seen in these patients.

Further, it is evident that a significant increase in pulmonary valve area occurred in 3 of the patients under 6 years of age. If body surface area and pulmonary valve area increase at a comparable rate, then the pulmonary valve index will remain unchanged. If, however, the pulmonary valve index increases significantly, one could postulate that the valve is growing proportionately more rapidly than the remainder of the body. Such was the case in 4 of our patients in whom the pulmonary valve index increased more than 10 per cent between catheterizations. Our experience and that of Moller and Adams (1965) indicates that mild to moderate valvular pulmonary stenosis usually does not increase in severity with age. It is evident that in the very young, significant valve growth does occur. Based on such experience, one might recommend that in those children with mild to moderate valvular pulmonary stenosis who present with minimal symptoms under 5 years of age, operation should be deferred until later in life. It is not inconceivable that certain subjects may show an improvement and reduction in gradient

commensurate with the increase in the pulmonary valve area, and may not require surgical correction. Such an hypothesis must await a more detailed evaluation of the natural history of this congenital lesion.

References

- Barritt, D. W. (1954). Simple pulmonary stenosis. *British Heart Journal*, **16**, 381.
- Campbell, M. (1960). Relationship of pressure and valve area in pulmonary stenosis. *British Heart Journal*, **22**, 101.
- , and Missen, G. A. K. (1959). Survival in good health until 65 years with pulmonary valvar stenosis. *Guy's Hospital Reports*, **108**, 390.
- Engle, M. A. (1957). Clinical conference — Pulmonic stenosis. *Pediatrics*, **19**, 1139.
- , Ito, T., and Goldberg, H. P. (1964). The fate of the patient with pulmonic stenosis. *Circulation*, **30**, 554.
- Fabricius, J. (1959). *Isolated Pulmonary Stenosis*, p. 131. Munksgaard, Copenhagen.
- Gasul, B. M., Arcilla, R. A., and Lev, M. (1966). *Heart Disease in Children*, p. 790. J. B. Lippincott, Philadelphia.
- Gorlin, R. (1966). Shunt flows and valves areas. In *Intravascular Catheterization*, 2nd ed., p. 571. Ed. by H. A. Zimmerman. C. C. Thomas, Springfield, Illinois.
- Hugenholtz, P. G., Hauck, A. J., and Nadas, A. S. (1963). Accuracy of valve area calculation in assessment of stenotic lesions. *Circulation*, **28**, 740.
- McIntosh, H. D., and Cohen, A. I. (1963). Pulmonary stenosis: the importance of the myocardial factor in determining the clinical course and surgical results. *American Heart Journal*, **65**, 715.
- Moller, J. H., and Adams, P. (1965). The natural history of pulmonary valvular stenosis: serial cardiac catheterizations in 21 children. *American Journal of Cardiology*, **16**, 654.
- Nadas, A. S. (1963). *Pediatric Cardiology*, 2nd ed., p. 628. W. B. Saunders, Philadelphia.
- Schulz, D. M., and Giordano, D. A. (1962). Hearts of infants and children: weights and measurements. *Archives of Pathology*, **74**, 464.
- Sobin, S. S., Carson, M. J., Johnson, J. L., and Baker, C. R. (1954). Pulmonary valvular stenosis with intact ventricular septum: isolated valvular stenosis and valvular stenosis associated with interatrial shunt. *American Heart Journal*, **48**, 416.
- Tinker, J., Howitt, G., Markman, P., and Wade, E. G. (1965). The natural history of isolated pulmonary stenosis. *British Heart Journal*, **27**, 151.
- Vogel, J. H. K., Grover, R. F., and Blount, S. G., Jr. (1962). Detection of the small intracardiac shunt with the hydrogen electrode. A highly sensitive and simple technique. *American Heart Journal*, **64**, 13.
- Wood, P. (1956). *Diseases of the Heart and Circulation*, 2nd ed., p. 414. Eyre and Spottiswoode, London.