THE EISENMENGER SYNDROME

Parkland Memorial Hospital

Medical Grand Rounds

March 31, 1966

Dr. Victor Eisenmenger's original case report.

(Die angeborenen Defecte der Kammerscheidewand des Herzens. Zeitschrift fuer Klinische Medicin. 32(Supplemental issue): 1-28, 1897.)

Froim Richtman, 32-year-old, married, coachman from Krabaz, Hungary, was accepted in the Clinic on [redacted] 1894.

Besides his current illness, from which he has suffered since earliest childhood, he has not had rheumatic fever, or been febrile, or had any other illness.

He developed normally, progressed well in school. He got married when he was 20 and he has a healthy child.

Since his early childhood, his parents noticed the blue coloring of his skin, which increased greatly with the slightest exertion, such as crying, etc. Also, every exertion brought on shortness of breath; however, he could do his job as coachman quite well.

In [redacted] of 1894 the patient noticed for the first time, that without cause his legs began to swell and he suffered even more than before from shortness of breath and palpitation. This condition continued with changing intensity and made the patient come to the hospital.

The data given by the patient are very precise and confirmed by the visiting mother. The latter told that she, as well as her husband, had always been well and that the pregnancy, birth and childbed followed a normal course.

Present status: patient is rather tall, with heavy bone structure, moderately developed muscles, little panniculus adiposus. The skin and the visible mucous membranes were cyanotic to a high degree, especially the skin over the prominences. The neck long, of middle width; a slight swelling of the vena jugularis was noticeable, especially on the right side, and it had a distinct undulation.

Thorax rather long, of middle width, noticeably arched, abdomen slightly bloated, on the ankles and the backside of the thoracic skin slight edema. The end digit of the fingers slightly thickened, the nails considerably curved, claw-like. Over both anterior apices of the lung clear, full percussion sound, reaching on the right side to the lower edge of the 7th rib, on the left side to the upper edge of the 4th rib. Posteriorly, everywhere clear

full percussion sound in normal expansion, on auscultation the sign of a diffuse catarrh.

In the region of the heart a strong shock of the thoracic wall is noticeable, which spreads also beyond the normal limits of the heart. The apex beat is found in the 6th intercostal space, $6\frac{1}{2}$ cm to the outside of the mammillary line, at which place the cardiac dullness begins and reaches to the right 4 cm beyond the right sternal border.

At the base the cardiac dullness reaches to the 4th intercostal space from the mammillary line to the left sternal border. In the left side position, the apex of the heart shifts by about 1 cm to the left.

Over the apex of the heart a murmur accompanied by a palpable thrill can be heard in systole and a dull second sound. The murmur can be heard to the right in the entire area of the cardiac dullness. The maximum point is in the middle of the cardiac dullness and decreases in all directions in intensity, upwards and to the left faster than downwards and to the right. Over the aorta and the pulmonary artery it cannot be heard.

In the remaining cardiac orifices, the heart sound is somewhat duller, but clearer, the second pulmonary sound not accentuated.

The liver dullness extends beyond three fingerbreadths below the rib-cage and reaches on the left to the left mammillary line. The liver edge is plainly palpable, firmly rounded, the spleen dullness very much enlarged. Otherwise, no abnormalities are noted in the abdomen. Pulse rate is somewhat irregular (108), not full, artery soft, urine 1500 cm, straw colored, clear, acid, contains small amounts of albumin and scanty granulated casts. The examination of the blood was negative; Fleischl approx. 120%. Result of ophthalmoscopic examination: negative. Therapy: Digitalis 1.5: 1500.0, later on Diuretin 6.0 per diem.

Remarkable is the behavior of the pulse. After the irregularity had disappeared under the influence of the digitalis, the pulse was between 72 and 80.

Sometimes the frequency sank, to 42-46 and the numbers in between could not be observed, but each time it was recognizable that the pulse wave was doubled. In such a moment a pulse curve could be

registered. Unfortunately, it has been lost and therefore I have to limit myself to its description.

Two elevations always followed each other rapidly, and they were separated from the next one by rather long pauses. Between these two elevations, in which the second was considerably lower than the first one, the stylus did not sink to the axis of the abscissa. Both, especially the second one, showed pronounced dicrotic elevations - on the whole it was the curve of a pulsus bigeminus alternans. I could never find a doubling of the apical beat; still, I had the impression that the apical beat was of longer duration than normal.

However, on auscultation, the doubling of the heart action was sometime quite easily observed, even if the sounds corresponding to the second pulse wave were weaker.

Alerted by the repeated examinations in this direction, the patient explained that he could not only feel the doubling of the heart beat, but that he was able to produce it. For this purpose, he slowly turned on his right side and when with this movement he passed the right side position, the phenomenon indeed appeared. During the course of his illness the patient, who spent 4 months in the hospital, improved and worsened repeatedly.

Once, for several days, the appearance of a weak diastolic murmur at the point of the systolic maximum point was observed. Towards the end the edema became generalized, the patient became very weak, suffered from headaches and repeated vomiting, the pulse became irregular, almost impalpable and on the 13th of November, after severe hemoptysis, the patient suffered exitus letalis.

FINDINGS OF THE SECTION (Prof. Dr. Kolisko)

Clinical diagnosis: defectus septi ventriculorum; infarctus pulmonum.

Anatomical diagnosis: Defectus septi ventriculorum cordis (partis posterioris septi anterioris) subsequente hypertrophia cordis praecipue ventriculi dextri. Cicatrices multiplices myocardii ventriculi sinistri e myomalacia. Degeneratio myocardii adiposa incipiens. Hyperaemia mechanica universalis. Infarctus haemorrhagicus pulmonum.

The body tall, strongly built, thin. The skin pale yellow in the anterior parts, diffusely dark violet in the posterior parts, only in the face and on the neck cyanotic, the extremities marked with

striped and dotted blood effusions; the subcutaneous parenchyma with the exception of head, neck and upper chest, highly swollen by edema, most pronouncedly so at the lower extremities. The visible mucous membranes cyanotic, the pupils dilated, the neck short, the thorax long, wide, arched, the abdomen flat. At the end phalanges of the upper extremities slight thickening of the bone noticeable (drumstick finger).

The scalp plethoric; the skull spacious mesocephalically, thin walled, compact; the dura taut and plethoric, the arteries bursting with fluid blood. The inner meninges plethoric, delicate, along the medial border of the hemisphere covered with pacchinoid granulations. The brain somewhat swollen and softer, the cortex grayish-purple everywhere, the medulla, on section, showed innumerable blood dots, in the semioval center also isolated capillary blood effusions. In the left gyrus fornicatus, near the corpus callosum, the cortex is replaced by a sclerotic gray growth the size of a pea. The chambers are narrow; the tela chrioidea is plethoric, the basal cerebral arteries have delicate walls. On opening the abdominal cavity, $\frac{1}{2}$ liter of serous clear fluid was found. The diaphragm is high on both sides.

The upper half of the pericardium is covered by the bloated edges of the upper lobes which touch each other, the lower half lies free 14 cm wide, and the anterior edge of the left lower lobe is pushed back to the anterior axillary line. After the lung borders have been pulled back, the pericardium appears so enlarged, that its width comes to 20 cm and its height to 16 cm. In the pleural spaces there is $\frac{1}{4}$ liter of serum each, the lungs are lightly adherent in the posterior periphery.

The enlargement of the pericardium seems to be affected by the enormous enlargement of the heart itself, in the pericardial cavity only 1/8 liter of serum is found. The pericardium is cyanotic, smooth and shiny in both lobes.

The heart is 5 times enlarged, approx. 20 cm wide and 16 cm long; the most enlarged part is the right atrium, which is larger than a man's fist. Both ventricles are bulging greatly, especially the right one, both have rigid walls; the large vessels at the base of the heart appear in normal position to each other, but are noticeably dilated; the pulmonary veins enter the pericardial cavity like sausages the size of a thumb.

On the left ventricle, namely towards the apex, numerous fibrous callous places of the musculature glisten through the pericardium; they are jagged, lentil-sized to penny-sized. All pericardial

cavities are greatly enlarged and are bursting with slightly clotted and fluid, blackish-red blood.

The left ventricle is 8-10 mm thick, contains at its bulging apex a globulous vegetation the size of a pidgeon egg; it is centrally softened; its flesh is dark red-brown, covered with callosities, especially at the apex of its posterior wall; the endocardium is tender and shows in places the yellow tiger stripes of the inner muscle layers; the papillary muscles are thin and stretched at the apices, fibrous; the trabeculations are stretched, in some places almost membranous; its venous ostium is widened (3 fingers can pass through), the apices of the bicuspid valve are very delicate; like they are stretched, so are the cords, which are taut; the left atrium is moderately dilated, thin walled, in the left side of the atrial septum no abnormality is found.

The right ventricle nearly the size of a man's fist, its wall is thickened up to 10 mm, its trabeculations and papillary muscles are thickened and greatly protruding; the endocardium is delicate, it shows here and there the yellow tiger stripes of the inner layers of the otherwise dark-red musculature. The right venous ostium is rather wide (4 fingerbreadths), the valves are markedly fibrous and enlarged, especially in the inner apex; so are the cords, without really a visible deformation.

The conus of the pulmonary artery is normally situated to the right ventricle and moderately enlarged but has in the posterior part, which corresponds to the anterior ventricular septum, a large, circular defect, which creates a communication the size of a thumb, between the two ventricles. This defect, situated anteriorly to the inner apex of the tricuspid valve, is bordered on the lower side by the fleshy upper border while in the back it is defined by the fibrinous, thickened and ledge-like septum membranaceum. Upwards the defect is so situated with relation to the aorta, that its lumen falls half in the right and half in the left ventricle. The aortic valves themselves are delicate and although the right and posterior one is pulled down somewhat toward the defect, it can close. The pulmonary valves are delicate and can close also.

The right auricle, enlarged the most, has a very thin wall, its endocardium is delicate. The venae cavae entering it are not markedly enlarged; on the septum, corresponding to the location of the foramen ovale, a ledge-like, fibrinously thickened, $\frac{1}{2}$ cm long, oblique endocardial ridge can be found. The orifice of the coronary vein is very wide.

The somewhat enlarged pulmonary artery shows at its inner surface end-arterial-like thickenings, which go all the way into the main branches of the vessels.

The aorta, however, which is of normal dimensions, is thin-skinned and smooth on its inner surface.

The ostia of the coronary arteries are wide, the coronary arteries have delicate walls. In place of the Ductus Botalli only the usual fibrous cord can be found.

The veins in the neck are somewhat dilated, the left jugularis interna is obstructed by a loose blackish-red thrombus, which continues as a brown, marginal and firmer attached thrombus of the left innominate by which the orifice of the jugularis is displaced.

The oral and pharyngeal cavities, the larynx, the trachea, and the bronchi are empty, the mucous membranes cyanotic everywhere. The lungs emphysematous, plethoric, flooded by frothy serum, inside the left upper lobe and the left lower lobe permeated with a blackish-red, hemorrhagic infarct, in which vessels obstructed by the thrombus can be found. The liver is plethoric, somewhat firm. The spleen is doubled in size, plethoric, firm.

The kidneys enlarged, very hard, dark brownish-red, the cortex which in traces is spotted yellow shows isolated small foci of ischemic necrosis. Bladder contracted, genitalia not remarkable.

Stomach contracted, the mucous membranes cyanotic; mucilaginous gall covers the duodenum, in the ductus coledochus there is mucinous gall also.

Small intestines contracted, mucous membranes cyanotic. In the cecum and ascending colon a blackish-red hemorrhagic pulpy mass, the mucous membranes cyanotic and ecchymosed.

In the remaining large intestine, feces gall yellow in color, mixed with mucus.

(Translated courtesy of Brigitta Payne.)

Case #1 - [redacted] Eisenmenger's Syndrome

26-year-old [redacted] male with lifelong symptoms of easy fatigability, shortness of breath on exertion. The patient worked despite these symptoms and occasional "blackout spells" with exertion. Minimal cyanosis is noted to worsen on exertion. The patient's ability to work has been gradually diminishing and in recent years he has had several bouts of hemoptysis.

Physical examination: blood pressure 140/80; pulse 92. Slight white male who reveals mild cyanosis and clubbing. Heart: right ventricular heave, regular rhythm, very loud P_2 with fixed spitting, variable soft systolic murmur at upper left sternal border.

Hemoglobin: up to 19.6 gm% - lowered by phlebotomy.

Electrocardiogram: right axis deviation, right ventricular hypertrophy.

X-rays: cardiac size at upper limits of normal. Pulmonary artery large, right ventricle large.

Lung biopsy ([redacted]/65): no significant arterial or arteriolar changes seen.

Cardiac Catheterizations

	1954		1962		1963	
Site	Pressure	O_2 sat	Pressure	O_2 sat	Pressure	O_2 sat
RA	$\overline{4}$	72	$\overline{4}$	67	$\overline{3}$	61
RV	65/38	83	100/4	67	109/7	68
PA	63/32, $\overline{40}$	79	108/80, 88	74	118/75	78
AO	90/50, $\overline{64}$	93			120/85, 103	88
LV					124/11	

L → R 1.75 L/min

R → L 1.0 L/min

Case #2 - [redacted] Eisenmenger's Syndrome

12-year-old [redacted] male with long history of mild cyanosis aggravated by exertion and limited exercise tolerance. The patient is slender but tall and well developed. The prominent findings are right parasternal lift, very loud P_2 and no murmurs or gallops. Electrocardiogram showed right axis deviation, right ventricular hypertrophy, right ventricular strain, "RVSO". X-rays showed a nearly normal heart size, prominence of pulmonary artery and right ventricle with diminished peripheral pulmonary vascularity. No progression of x-ray or electrocardiographic findings noted between ages 7 and 12. He was submitted to a pulmonary artery banding procedure at age 12 followed by slight symptomatic improvement but definite worsening of his cyanosis.

Cardiac Catheterizations

	Age 8		Age 12	
Site	Pressure	O_2 sat	Pressure	O_2 sat
RA	$\overline{5}$	61	$\overline{5}$	63
RV	90/5	61	108/0-6	63
PA	120/78, $\overline{98}$	-	-	-
Wedge	-	-	-	-
AO	120/80, $\overline{98}$	74	106/60, $\overline{76}$	78

SBF (L/min)	3.2	5.04
PBF (L/min)	1.7	2.1
R → L (%SBF)	47	58
PVR (μ)	> 28	

Addendum Follow-up (courtesy of Martha Carpenter, M. D., Department of Surgery, University of Virginia Hospital, Charlottesville): This 19-year-old boy (seen [redacted]/66) has been followed in this hospital with the diagnosis of Eisenmenger's complex with a ventricular septal defect. In [redacted] 1960 he underwent cardiac catheterization which showed equal pressures on both sides of the heart and peripheral arterial desaturation to 65%. It was felt that the only way in which he could possibly be helped was pulmonary artery banding. This was carried out in [redacted] 1960, but the pulmonary artery could not be narrowed as much as was felt optimal because

Case #2 - [redacted] - Continuation

of cardiac slowing. However, the pulmonary artery was narrowed approximately 30% and there was a thrill distal to the band. Since his operation he has done much better than previously and is now able to work a full day and walks any distance he wants to without stopping. There have been no difficulties with infection or other difficulty within the past year. He continues to be quite cyanotic.

Physical examination: reveals a small, thin, boy in no acute difficulty. He is markedly cyanotic at rest, and there is moderate clubbing. Chest is clear. There is a right ventricular impulse maximal at the lower left sternal border. No thrills are palpable. First heart sound is normal and maximal at the apex. The second heart sound is narrowly split and maximal at the upper left sternal border with a markedly accentuated pulmonary closure sound. There is a grade II very short systolic ejection murmur maximal at the upper left sternal border and a peculiar twanging diastolic sound. The liver and spleen are not enlarged. The peripheral pulses are normal and equal.

Chest film: shows normal cardiac size with a rounded globular configuration and dilated main pulmonary artery segment. Pulmonary vascularity is decreased peripherally. Comparison with the preoperative chest film shows that the heart now has a much more globular configuration; but, otherwise, there is not too much change.

Electrocardiogram: shows a QRS axis of +110 and right ventricular hypertrophy. In addition there are pretty good ventricular potentials on the left.

Impression: This patient has a ventricular septal defect with marked pulmonary artery hypertension and pulmonary vascular obstruction as shown by his previous catheterizations. Pulmonary artery banding was done in August 1960; but I would doubt that there is any significant gradient across his band or that he was helped significantly by the banding, although he has done better symptomatically since then. Since he has not been catheterized post-banding I think he should be scheduled for cardiac catheterization in order to determine just what his situation is now and whether or not any further surgical intervention might help him. Hematocrit today is 64%; hemoglobin 21.7 gm.

Case #3 - [redacted] Small VSD

History: 5-year-old [redacted] female with known murmur since birth. Patient has always tired more easily than her sibling, eats poorly, had pneumonia at age 3 months and frequent upper respiratory infections until 6 months prior to examination. No cyanosis, fainting or overt failure.

Physical examination: blood pressure 114/60; 25 percentile for height and weight. Thrill at left sternal border, P_2 normal, third sound at apex. Grade IV/VI pansystolic murmur at left sternal border loudest at fourth intercostal space.

Electrocardiogram: semi-vertical axis; QRS amplitude suggestive of left ventricular hypertrophy.

X-rays: full heart consistent with minimal right ventricular enlargement, left ventricular enlargement and left atrial enlargement.

Cardiac Catheterization

Site	Pressure	O_2 sat			
SVC	$\overline{4}$	67	PBF	3.5	L/min
RA	$\overline{4}$	68	SBF	2.6	
RV	27/2-8	76	L → R	0.9	
PA	$\overline{16}$	75	PBF:SBF	1.3:1	
Wedge	$\overline{10}$	-	PVR	1.7	μ
AO	112/56, $\overline{76}$	95	Dye curves	Small L → R	

Comment: The history, electrocardiographic and x-ray findings are suggestive of a decrease in the volume of left-to-right shunt. Early spontaneous closure of ventricular septal defects is relatively common and late closure or relative decrease in size has been documented also.

Case #4 - [redacted] Moderate VSD

9-year-old [redacted] female, asymptomatic. Heart murmur discovered at age 6 weeks. 15th percentile for age in weight. Three siblings living and well.

Physical examination: blood pressure 105/70. Slight cardiomegaly, precordial thrill and loud, rasping grade V/VI holosystolic murmur loudest fourth intercostal space at left sternal border. Third sound at apex. P_2 normal.

Electrocardiogram: horizontal axis, left ventricular hypertrophy, LVDO.

Fluoroscopy: prominent pulmonary artery, left ventricle, left atrium, ?right ventricle.

Cardiac Catheterization

Site	Pressure	O_2 sat			
SVC	$\overline{1}$	70	PBF	7.67	L/min
RA	$\overline{1}$	70	SBF	3.86	
RV	19/0-6	82	L → R	3.81	
PA	20/8, $\overline{12}$	82	PBF:SBF	2:1	
Wedge	$\overline{6}$	-	PVR	< 1	μ
AO	120/68, $\overline{86}$	97	Dye curve	L → R	

Comment: Low pressure, moderate flow. At the present time correction of this type lesion is frequently advised. There is much data to suggest that this type remains stable and is compatible with normal activity and life span threatened principally by an approximately 5% chance of endocarditis and a poor tolerance for the additional burdens of hypertension or ischemic heart disease occurring later in life.

Case #5 - [redacted] Large VSD

5-year-old [redacted] female who had normal growth, development and was asymptomatic. No cyanosis.

Physical examination: blood pressure 104/56. No cyanosis or clubbing. Positive findings were: heart enlarged to right and left, thrill felt left third intercostal space at left sternal border with an associated grade IV/VI holosystolic murmur, P_2 loud and normally split, third heart sound heard at the apex.

Electrocardiogram: first degree heart block, "P congenitale", combined ventricular hypertrophy, left ventricular diastolic overload.

X-rays: markedly enlarged heart with biventricular enlargement, prominent pulmonary artery, pulmonary plethora.

Cardiac Catheterization

Site	Pressure	O_2 sat	
SVC	$\overline{6}$	65	PBF:SBF approx 2:1
RA	$\overline{4}$	65	
RV	80/0-5	85	
PA	83/45, $\overline{55}$	85	

Comment: Surgery was considered urgent (1958). At operation the patient had a large, high ventricular septal defect. The defect was closed but an aortic cusp was inadvertently torn. Patient died after ten days of unrelenting heart failure.

Although this type may occasionally progress to higher pressures with decreases in left-to-right shunt, many have shown no change and some spontaneous improvement during the childhood-adolescent years.

Case #6 - [redacted] [redacted] Patent Ductus with Reversal of Flow

33-year-old [redacted] male felt well until age 15 when he experienced an episode of hemoptysis while riding his bicycle up a steep hill. A heart murmur had been known to be present since childhood, but he had been asymptomatic until this occasion. He was then without symptoms until age 25 when he had a massive hemoptysis while taking a shower. He was referred to Dr. A. Nadas of Boston. Hemoglobin 18.4; electrocardiogram - right ventricular hypertrophy. Cardiac catheterization (data available to us below) interpreted as demonstrating severe pulmonary hypertension with bidirectional shunting probably through a ventricular septal defect. 1½ years ago he developed dyspnea on exertion, pedal edema, ascites and cyanosis and was admitted to [redacted]. Dr. Bashour noted that clubbing and cyanosis of toes were more pronounced than that of the fingers. Hemoglobin 25.6. He improved after phlebotomy, digitalis, bedrest. In [redacted] 1966 he complained of increasing dyspnea, orthopnea and edema. Hemoglobin 17. Improved after phlebotomy.

Physical examination: blood pressure 130/80; pulse 88; respirations 18. Well developed, slightly plethoric white male. Slight venous distention. Cyanosis and clubbing of toes more marked than that of the fingers. Heart: Left border of cardiac dullness at midclavicular line. Regular rhythm. Right ventricular heave. Grade III/VI rough diastolic murmur at left sternal border. A short systolic murmur at third intercostal space at left sternal border. Pulmonic second sound loud and widely split. Liver edge 3 fb below right costal margin. Hemoglobin 17.

X-ray: prominent pulmonary artery and right ventricular enlargement.

Electrocardiogram: Right bundle branch block, right ventricular hypertrophy, right ventricular strain.

Cardiac Catheterizations

Site	Age 25 Pressure	Age 33 Pressure	O_2 sat
SVC			
RA		$\overline{14}$	58
RV	160/20	134/14	58
PA			
Asc AO	140/80		92
Desc AO		121/76, $\overline{98}$	77

PVR 43 μ
L → R 0.69 L/min
R → L 0.77 L/min

Dye: R → L
Cine: PDA with L → R, ?R → L

Case #7 - [redacted] [redacted] Patent Ductus, Severe Pulmonary Hypertension, No R → L Shunt

23-year-old [redacted] female with known murmur since age 3 months. Three episodes pneumonia as child. Catheterized elsewhere at age 12 - results and recommendations unknown to patient. Never able to keep up with contemporaries and has always complained of dyspnea on exertion which has been gradually worsening, especially during past 6 months. Has had occasional paroxysmal nocturnal dyspnea, palpitations and weak and dizzy spells. Can now walk only one block without dyspnea.

Physical examination: blood pressure 100/70; pulse 92; respirations 20; temperature 98. Thin, small white female. No cyanosis, but clubbing of fingers and toes noted. Heart: enlarged to anterior axillary line with active apex impulse. P_2 greater than A_2. Grade IV/VI systolic murmur over precordium with radiation to neck and axilla. A grade II/VI decrescendo diastolic murmur heard down left sternal border. Laterally in second to third intercostal space a diastolic component continuous with systolic murmur was heard.

Hemoglobin 22; hematocrit 65; white blood count 8,000.

X-ray: left ventricular enlargement and prominent pulmonary artery and pulmonary plethora.

Electrocardiogram: left ventricular hypertrophy, left ventricular strain.

Cardiac Catheterization

Site		Pressure		O_2 sat			
RA		$\overline{5}$		74	SBF	3.0	L/min
RV		98/6		74	PBF	3.9	
PA	*	110/61		79	PVR	16	μ
Wedge		$\overline{19}$		-	SVR	25	μ
AO		116/64	Arch Desc AO	98 95			

Dye: No evidence R → L; Cine: L → R through patent ductus arteriosus; minimal aortic stenosis and aortic insufficiency.

* No change while breathing 100% O_2.

Case #8 - [redacted] - [redacted]

Atrial Septal Defect, Pulmonary Hypertension - Demonstrating development of RV failure and development of R → L shunt

34-year-old [redacted] male had been well until 5 years ago when he had bronchopneumonia complicated by allergic reaction to penicillin. Progressively severe shortness of breath noted since that time until at present walking across a room or dressing himself is attended by rather acute, severe dyspnea. Ten and 2 months prior to being seen he had hemoptysis - on one occasion he brought up about a cupful of bright red blood. No cyanosis, edema but has had pain in the midchest after exertion. Thirteen years ago, the patient was able to walk up a steep mountain at an ambient temperature of 40° below zero without complaint.

Physical examination: blood pressure 170/100; pulse 90 and regular. Well developed white male in no distress. Heart: left border of cardiac dullness 11 cm lateral to the midsternal line. P_2 widely split and somewhat loud. No murmurs.

Hemoglobin 15.6.

X-rays and fluoroscopy: dilatation proximal pulmonary arteries with decreased peripheral pulmonary vasculature.

Electrocardiogram: right ventricular hypertrophy, right ventricular strain.

Cardiac Catheterizations (Dyspnea worsened between caths.)

Site	[redacted]/63 Pressure	O_2 sat		[redacted]/63 Pressure	O_2 sat
SVC	$\overline{4}$	77		$\overline{19}$	51
RA	$\overline{3}$	-		19	-
RV	100/0	85		104/2-21	-
PA	90/40, $\overline{70}$	86		112/45, $\overline{65}$	63
Wedge	$\overline{7}$	-	$\bar{PA}$ 100% O_2	108/49, $\overline{67}$	-
LA	$\overline{5}$	95	$\bar{PA}$ ex	131/54, $\overline{81}$	-
LV	125/0	95		-	-
BA	120/70, 90	95		152/98, 118	89
PBF (L/min)	12			10.2	
SBF (L/min)	6.7			6.8	
PBF:SBF	1.8:1			1.5:1	
PVR (μ)	5.3			6	
Dye	Small L → R; no R → L			L → R and R → L	

Case #9 - [redacted] Multiple Peripheral Pulmonary Artery Stenoses

22-year-old [redacted] female complained of shortness of breath and occasional fainting after exertion since childhood. Despite these complaints she had led a rather active life.

Physical examination: well developed, well nourished woman. Cuff blood pressure 124/64. P_2 was palpable and markedly accentuated. At the apex the first sound was loud and diastole was clear. Just medial to the aortic area, as well as in the infraclavicular areas and over the mid-dorsal paravertebral areas, was heard a faint high-pitched murmur starting early in systole, reaching its greatest intensity at the time of the second sound and continuing thereafter through most of diastole. The remainder of the examination was normal.

Laboratory findings: hemogram and urine were normal. Electrocardiograms demonstrated right axis deviation and right ventricular hypertrophy. Chest x-ray films and fluoroscopy demonstrated slight enlargement of the right ventricle, prominent pulmonary artery pulsations of the hilar vessels and decreased peripheral pulmonary vascularity.

Right heart catheterization: right ventricular pressure 105/0; pulmonary artery pressure 105/40, mean 70; normal wedge pressure and brachial arterial pressure 140/90, mean 115. The data did not suggest a shunt; cardiac output by the Fick method was 3.5 L/min, yielding a low cardiac index of 2 L/min/m^2.

Angiocardiography: selective angiocardiograms with injection into the main pulmonary artery revealed the smaller vessels in the periphery of the lung fields to be definitely diminished in caliber. In several areas it appeared as if the middle sized vessels were stenotic and narrowed abruptly. A lung biopsy was performed revealing no abnormalities of the smaller vessels. Thus, it appeared reasonably well established that the patient had multiple stenoses of the pulmonary artery.

Comment: Although the findings at catheterization were consistent with idiopathic pulmonary hypertension, the lifelong history of debility and the atypically located continuous murmur suggested that this diagnosis might be incorrect. The presence of atypically located systolic or continuous murmurs in a patient with otherwise unexplained pulmonary hypertension should suggest the possibility of single or multiple peripheral pulmonary artery stenosis.

In this case, simple catheterization of the pulmonary artery did not demonstrate the lesion(s). The confirmation of a presumed

Case #9 - [redacted]. - Continuation

"wedge" pressure by the withdrawal of a blood sample is probably necessary in order to establish the position of the catheter tip in such cases. Selective angiography from the main pulmonary artery or right ventricular outflow tract yields the most complete diagnostic information.

From Shapiro: Am. J. Cardiol. 7:511, 1961.

Case #10 - [redacted] Aortic-Pulmonary Window

A 30-year-old [redacted] female complained of excessive fatigue. She had two living children. The second pregnancy at age 30 was complicated by a breech presentation, the delivery requiring about six hours.

Physical examination: moderate cyanosis with clubbing was evident. She had a left parasternal heave, a very loud P_2, a faint, short systolic murmur at the upper left sternal border and a grade I decrescendo diastolic murmur heard down the left sternal border. The heart was small and the peripheral lung fields clear. RBC 5.8 million.

Electrocardiogram: right axis deviation, right ventricular hypertrophy, right ventricular strain.

Cardiac Catheterization

Site	Pressure	O_2 sat
RV	-	64
PA	106/66	73
FA	116/64	90

PBF:SBF = 1:1

A catheter was passed retrograde into aorta and entered the pulmonary artery. Injection by this means into the pulmonary artery confirmed the location of the defect and the presence of right-to-left shunting.

Causes and Frequency of Eisenmenger's Syndrome*

		Total no. of cases	No. with Eisenmenger reaction	Frequency of Eisenmenger reaction (%)
I.	Patent ductus arteriosus	180	29	16
II.	Aorto-pulmonary septal defect	10	6	60
III.	Persistent truncus arteriosus	4	4	100
IV.	Transposition of the great vessels (with V.S.D.)	12	7	58
V.	Corrected transposition (with V.S.D.)	3	3	100
VI.	Single ventricle	6	6	100
VII.	Ventricular septal defect	136	21	16
VIII.	Common atrio-ventricular canal or persistent ostium primum	21	9	43
IX.	Single atrium	--	--	
X.	Atrial septal defect	324	19	6
XI.	Hemianomalous pulmonary venous drainage	3	0	0
XII.	Total anomalous pulmonary venous drainage	6	1	17
	Site uncertain	22	22	
		727	127	17.5

* From Wood: Brit. Med. J. 2:701, 1958.

Frequency of the Eisenmenger Reaction in Relation to the Site and Size of the Defect*

Site of communication	Total no. of cases	No. with large defects	No. with Eisenmenger reaction	No. with Eisenmenger reaction expressed as percentage of large defects
Aorto-pulmonary	190	66	35	53
Interventricular	179	97	50	52
Interatrial	333	214	20	9

Onset of Eisenmenger Syndrome*

	Duct. %	V.S.D. %	A.S.D. %
Infancy	79	83	8
Childhood and adolescence	4	15	-
Adult life	17	2	92

Symptoms of Eisenmenger Syndrome*

	Duct. %	V.S.D. %	A.S.D. %
Angina	20	14	15
Syncope	15	14	10
Haemoptysis	12	33	25
Congestive failure	12	8	10

* From Wood: Brit. Med. J. 2:701, 1958.

Ventricular Septal Defect - Classification and Hemodynamics*

	Uncomplicated by elevated pulmonary vascular resistance			Complicated by elevated pulmonary vascular resistance	
	Mild	Moderate	Severe	Pulmonary hypertensive	Eisenmenger complex
Group no.	1	2	3	4	5
No. cases	175	98	18	63	70
percent of total	41.2	23.2	4.2	14.9	16.5
Age					
Average	16.4	13.8	17.2	10.3	20.8
Median	14	10	11	6	22
Range	3-71	1-44	3-35	1-25	5-44
Pf:Sf flow ratio†	1.1-1.7	1.8-2.9	> 3.0	1.5-3.5	0.5-1.5
RV systolic pressure (mm Hg)					
Average	21	24	35	82	Systemic
Range	12-30	15-40	20-70	60-systemic	--
Pulmonary artery mean pressure (mm Hg)					
Average	13	18	38	56	Systemic
Range	5-20	5-30	12-55	35-systemic	Systemic
Pulmonary vascular resistance (units)					
Average	1.25	1.1	2.0	6.2	20
Range	0.4-2.2	0.4-2.5	0.8-4.0	3-10	10-40+
Hyperkinetic pulmonary hypertension	None	None to mild	Moderate to severe	Severe	None
Size of defect (cm)					
Average	0.4	1.0	2.0	2.2	2.2
Range	0.1-0.6	0.7-1.2	1.5-2.0+	1.5-3.0	1.5-3.0

* From Bloomfield: Circulation 29:914, 1964.

† Pulmonary-to-systemic flow ratio.

Criteria of Severity of Ventricular Septal Defect*

Grade of severity	Hemodynamics†	Electrocardiographic findings	Roentgenogram of thorax	Signs and symptoms
0	Q_p/Q_s < 1.5 P_p/P_s < 0.3	Normal	Normal	None
1+	Q_p/Q_s > 1.5 P_p/P_s Up to 0.75	LVH only	C/T < 0.6 and pulmonary vasculature slightly increased	Fatigue
2+	Q_p/Q_s > 3.0 P_p/P_s > 0.75	LVH + RVH	C/T > 0.6 and moderate to marked increase in pulmonary vasculature markings	Congestive heart failure
3+	Q_p/Q_s < 1.5 P_p/P_s > 0.75	RVH only	Normal heart size and pulmonary artery segment large	Cyanosis, syncope, hemoptysis

* From Ritter, et al: Circulation 32:III-42, 1965.

† Q_p/Q_s = ratio of pulmonary to systemic flow. P_p/P_s = ratio of pulmonary to systemic external pressures.

Progressive Pulmonary Vascular Disease in Six Cases of Ventricular Septal Defect*

Patient	Sex	Cardiac catheterization				Status and age when last seen
		Procedure	Age (years)	Data Q_p/Q_s	Data P_p/P_s	
1	M	First	1/3	4.4	0.75	Operation at age 3; died
		Second	2 1/2	2.6	1.0	
2	M	First	5/12	3.0	0.9	Operation at age 5; alive at age 7 with pallor and syncope
		Second	4	1.7	1.0	
		Third†	7	1.0	0.92	
3	F	First	3	2.5	1.0	Not known
		Second	7	1.5	1.0	
4	F	First	9	2.7	0.5	Operation at age 17; died
		Second	17	1.7	1.0	
5	F	First	9	2.5	1.0	Dizzy spells, angina with exercise at age 16
		Second	16	1.4	1.0	
6	F	First	17	1.9	0.75	Operation at age 18; alive at age 19
		Second†	19	1.0	1.0	

* From Ritter, et al: Circulation 32:III-42, 1965.

† Postoperative catheterization

Pulmonary Arterial Pressure Decrease*

Case	Pressure		Decrease, systolic
	Initial	Restudy	
1	42/24 (32)†	21/9 (16)	21
4	96/66 (82)	70/35 (49)	26
6	68/45 (53)	50/22 (41)	18
9	105/60 (81)	80/35 (56)	25
12	56/31	44/16	12
13	30/15 (24)	18/9 (16)	12
17	31/15 (24)	20/12 (14)	11
22	43/15 (24)	29/15 (20)	14

Data for Recatheterized Patients with Ventricular Septal Defect*

Source	Patients (no.)	Time interval (yr)	PA pressure increase
Adams et al.	30	1-8	13 (43%)
Brotmacher and Campbell	3	7	1
Downing	20	1 5/12-8	1 (5%)
Lynfield et al.	32	1-7	2 (6.3%)
Nadas et al.	25	1-8	None
Dammann et al.	6	1 5/12-9	None
Present series	23	2-7	None
Total	139		17 (12.2%)

* From Stanton and Fyler: Pediatrics 27:621, 1961.

† Figure in parentheses represents mean pressure.

Reported Pulmonary Arterial Pressure Increases*

Source	Patients (no.)	Pressure		Interval (yr)
		Initial (mm Hg)	Restudy (mm Hg)	
Lynfield et al.	2	77/35	92/57	3
		77/47	103/66	4
Downing	1	80/60	92/40	3
Brotmacher and Campbell	1	88/50	120/65	7
Adams et al.	13	†	†	

Reported Percentages of Increased Systolic Pulmonary Arterial Pressure*

Source	Patients (no.)	Increased pressure	
		no.	%
Lynfield et al.	32	2	6.3
Downing	20	1	5
Brotmacher and Campbell	3	1	
Adams et al.	30	13	43
Total group	139	17	12.2
Group, exclusive of Adams	109	4	3.7

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