ACYANOTIC FALLOT'S TETRALOGY : A CLINICAL REPORT OF SIX CASES*

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The clinical picture in Fallot's tetralogy ranges from the very severe form with marked pulmonary stenosis and significant right-to-left shunt, on the one hand, to the form with mild pulmonic stenosis and primarily a left-to-right shunt, on the other (Fig. 1). The above varieties have 3

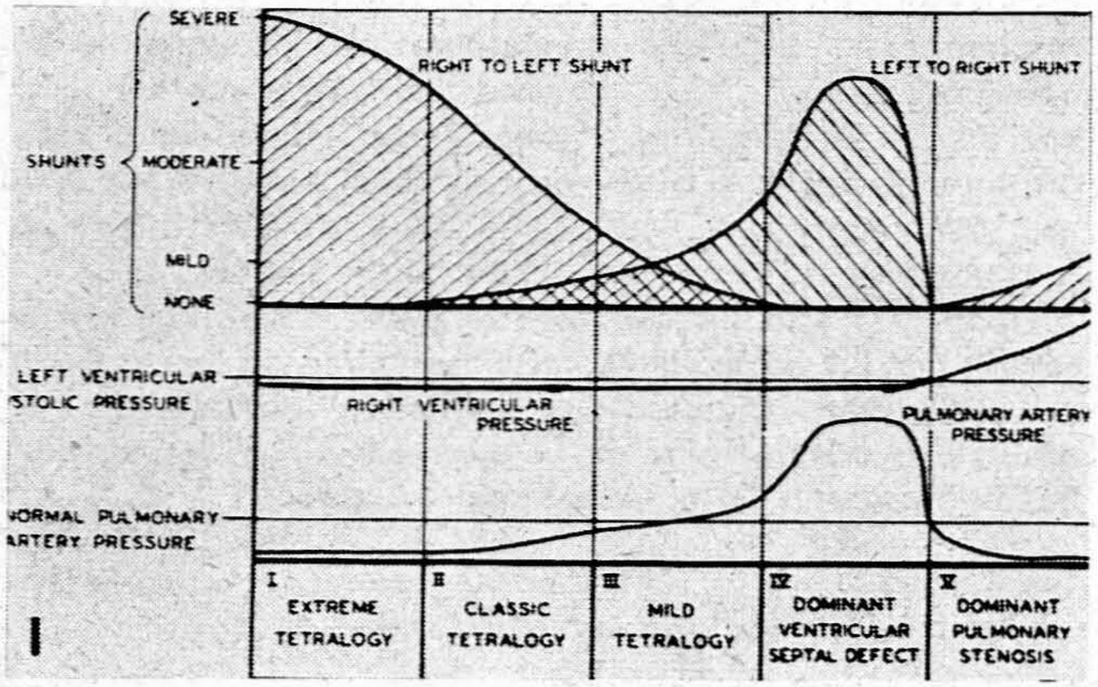

Fig. 1. The 'spectrum' of ventricular septal defect and pulmonary stenosis (modified from McCord *et al.*[11]) Groups I, II and III are tetralogies. Group IV may or may not be tetralogy.

fundamental features in common, viz. pulmonic stenosis (either infundibular or valvular or both), high ventricular septal defect, and equalization of systolic pressures in both right and left ventricles. All patients with Fallot's tetrad, severe and mild, are liable to have increased infundibular 'narrowing' with resultant blue or unconscious spells. The other aspects of Fallot's tetralogy—dextro-position of the aorta, right ventricular hypertrophy, and overriding of the ventricular septal defect by the aorta—are neither clinically nor haemodynamically important. This paper describes 6 patients with Fallot's tetralogy who were not cyanosed clinically, but who belonged haemodynamically to the tetrad group. The hazards of cardiac catheterization in patients with Fallot's tetralogy are confirmed.[1] One patient developed a syncopal spell during the investigation, and remained unconscious for $2\frac{1}{2}$ hours.[2]

* Paper presented at the 42nd South African Medical Congress (M.A.S.A.), East London, C.P., September - October 1959.

Methods

All the patients were examined clinically by at least 2 of the authors. A 12-lead electrocardiogram, full radiological survey, and phonocardiogram (Sanborn twin-beam), were performed in each case. In 5 cases cardiac catheterization was carried out under mild general anaesthesia with sodium thiopentone (pentothal) after premedication with meperidine hydrochloride (pethedine), nalorphine hydrochloride (lethidrone), prochlorperazine maleate (stemetil) and promethazine hydrochloride (phenergan). The 6th patient was catheterized under local anaesthesia.

The oxygen content of the blood was measured by the Van Slyke technique and the oxygen saturation by cuvette oximetry (Waters-Connoly oximeter). Pressures were recorded on a direct-writing recorder through a Sanborn capacitance electromanometer.

CLINICAL FEATURES

Symptoms

The clinical features are summarized in Tables I and II.

TABLE I. SYMPTOMS

Case No.	*Age*	*Sex*	*Dyspnoea*	*Cyanosis at rest*	*Cyanosis on crying*	*Cyanosis on exertion*	*Sweating*	*Failure to thrive*	*Respiratory infections*	*Squatting*	*Syncope*	*Angina*
1	4	M	+	—	+	+	—	+	+	—	—	—
2	$2\frac{1}{4}$	F	+++	—	+	+	—	—	—	—	once	—
3	$4\frac{1}{2}$	M	++	—	—	—	—	—	—	—	—	+
4	$4\frac{1}{2}$	M	+	—	—	+	+	+	++	+	once	—
5	5	F	+	—	—	—	—	—	—	—	—	—
6	17	M	+	—	—	—	—	—	—	—	—	—

+=mild. ++=moderate. +++=marked.

There were 4 boys and 2 girls. Their ages ranged from $2\frac{1}{4}$ years to 17 years. Shortness of breath on exertion was present in every case and every patient was more incapacitated in hot weather. Cyanosis at rest was absent in every patient, but cases 1 and 2 became cyanosed during crying and exertion. Case 4 occasionally showed cyanosis on exertion. Squatting was noted in case 4. Syncopal attacks occurred on only one occasion in each of 2 cases. Failure to thrive was a presenting symptom in 2 patients. Frequent upper-respiratory-tract infections were present in 2 patients. Excessive sweating was a feature in one boy and chest pain on effort in another boy.

Signs

All except case 1 were well developed and well nourished. A plethoric appearance was noted in all, but no definite cyanosis or clubbing. The finger tips were abnormally red in 5 out of the 6 cases. Blood-pressure readings were normal. A slightly collapsing pulse was noted in case 4. Cardiomegaly was not a feature and the heart action was quiet in all but one case. A right ventricular parasternal heave was palpated in all patients, while cases 3 and 6 had an apical left ventricular heave as well. Pulmonary systolic thrills were present in all and in case 4 a systolic thrill was present in the epigastrium as well. A systolic thrust in the pulmonary area was recorded in 3 patients and a diastolic shock in the same region in 2 patients. The first heart sound was normal in 5 patients and accentuated in 1 patient. The second heart sound was split in 5 patients; in 4 patients the 2nd component (pulmonary) was softer than the 1st, and in 1 patient they were equal; in case 4 the second heart sound was recorded as single. Ejection pulmonary systolic murmurs of grade 3 - 4 were present in all patients.

A rough early diastolic murmur replacing the 2nd component of the second heart sound was audible in case 4. This was found at open-heart surgery to be due to incompetence through a rudimentary, abnormally situated, extracardiac pulmonary valve. A rumbling apical mid-diastolic flow murmur (which disappeared after corrective surgery) was noted in case 3. There was no evidence of congestive cardiac failure, elevated jugular venous pressure, hepatomegaly, or peri-orbital oedema, in this series.

The electrocardiograms were abnormal in all cases. Right ventricular hypertrophy was present in every one.[3,4] The pattern, however, varied. A tall, notched, R pattern in VI was recorded in 3 cases—the voltage being 11 mm., 24 mm. and 26 mm. respectively (Fig. 2, case P.R.). An rsR′ configuration with a delayed onset of intrinsicoid deflection (0·04 second) was seen in one patient (Fig. 2, case J.R.). Two further patients had prominent S waves in lead 1 and tall R waves in lead 3—their axis deviation measuring +105° and +85° respectively. They also showed upright T waves in VI, reported as right ventricular hypertrophy in the first year of life by Ziegler[5] (Fig. 2, case C.J.). We have not seen this latter pattern in normal children under the age of 10 years and have regarded it as a sign of right ventricular hypertrophy in this particular age group. Only one patient showed left ventricular hypertrophy in addition to his right ventricular hypertrophy (Fig. 2, case C.J.). Abnormal P waves were not seen in this series.

Phonocardiography showed classical pulmonary ejection systolic murmurs in all cases. The systolic murmur occupied the whole of systole (Fig. 3). The second heart sound was

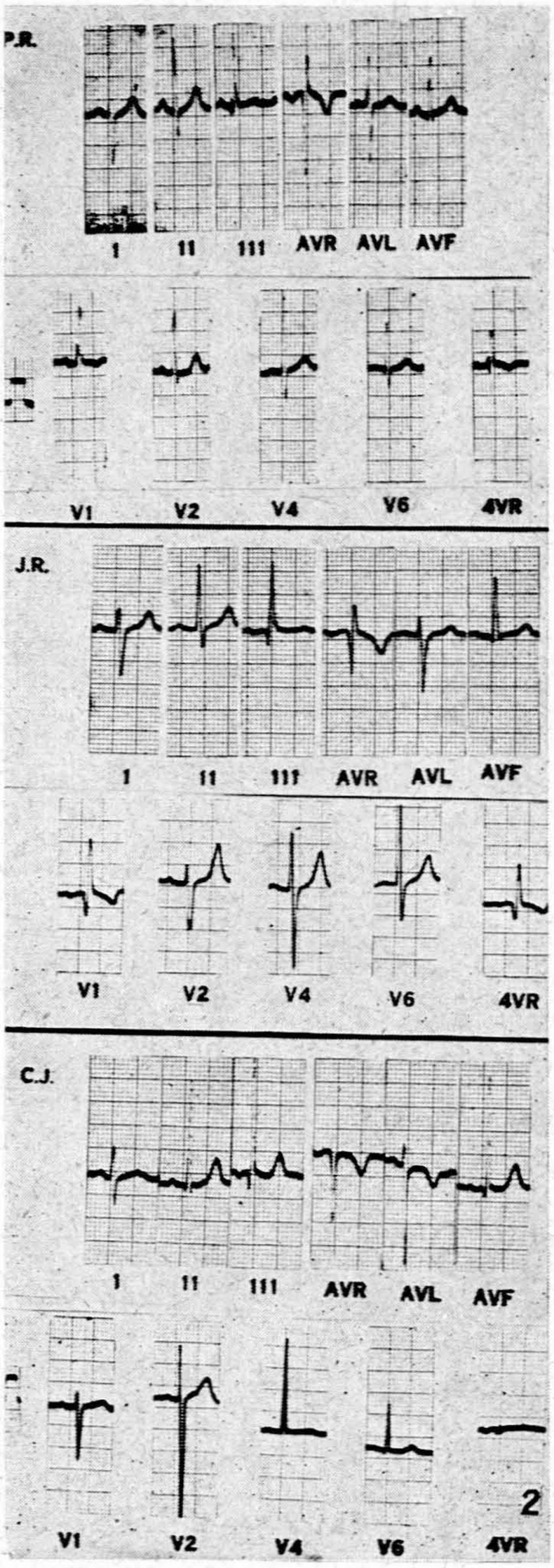

Fig. 2. Electrocardiographic patterns.

split in 5 patients, the second pulmonary portion being softer than the aortic element. The splitting was moderately wide, being 0·06 - 0·08 seconds. In case 4 the second sound appeared to be single. A pulmonary incompetence murmur replacing the 2nd component of the second sound was recorded in this case. An apical mid-diastolic murmur was recorded in 1 case (Fig. 3). Amyl nitrite was administered to 2 patients.[6] In one of them (case 6) the systolic murmur practically disappeared (Fig. 4), whereas in the other (case 4), while the

TABLE II. SIGNS

Case No.	Pleth.	Red fingers	Club-bing	BP mm. Hg	Cardio-megaly	Quiet heart	LVH	RVH	Syst. thrill	MI	P2	SM	MDM	EDM	CCF
1	+	+	? early	75/40	−	+	−	+	Pulm. area	Normal	Split, compo-nents equal	Gr. 4	−	−	−
2	+	+	−	90/50	−	+	−	+	Pulm. area	Normal	Split, 2nd com-ponent soft	ejec-tion Gr. 4	−	−	−
3	+	+	−	90/60	−	+	+	+	Pulm. area	Normal	Split, 2nd com-ponent soft	Gr. 4	Gr. 2 at apex	−	−
4	+	+		110/70	−	+	−	+	Epigas-trium Pulm. area	Normal	Single	Gr. 5	−	Gr. 2 harsh at Pulm. area	−
5	+	+	−	90/65	+	−	−	+	Pulm. area	Normal	Split, 2nd com-ponent soft	Gr. 4	−	−	−
6	+	−	−	110/70	+	+	+	++	Pulm. area	Accen-tuated	Split, 2nd com-ponent soft	Gr. 6	−	−	−

Pleth=Plethoric appearance. LVH=Left ventricular enlargement. RVH=Right ventricular enlargement. M1=First heart sound at apex. P2=Second heart sound at pulmonic area. SM=Systolic murmur. MDM=Mid-diastolic murmur. EDM=Early diastolic murmur. CCF=Congestive cardiac failure.

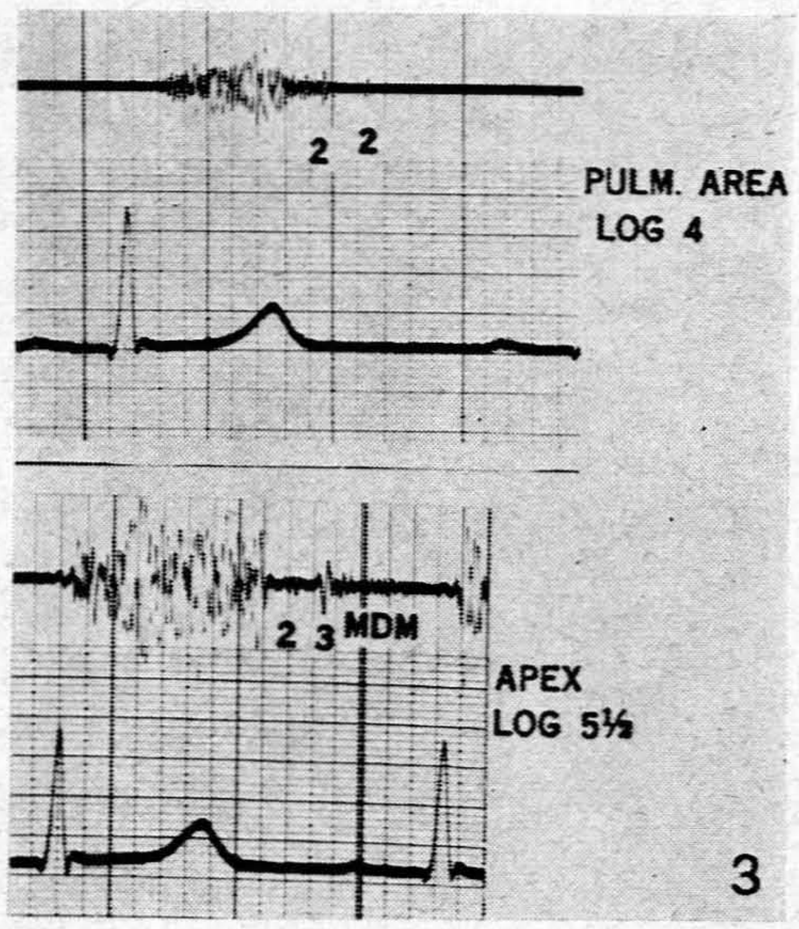

Fig. 3. Phonocardiogram showing ejection systolic murmur, wide splitting of 2nd sound with soft second component, and mitral flow murmur.

TABLE III. X-RAY FEATURES

Case No.	CTR	PAS	PV	RA	LA	RV	LV	Aorta
1	50%	N	±	N	+(DD)	+	+	High Prom.
2	58%	N	N	±	N	+	N	Prom.
3	51%	+	+	+	+(DD)	+	+	N
4	50%	N	+	+	N	+	N	N
5	50%	N	+	N	+(LAA)	+	N	N
6	50%	+	+	+	N	+	+	High Prom.

CTR=Cardiothoracic ratio. PAS=Pulmonary artery segment. PV=Pulmonary vasculature. RA=Right atrium. LA=Left atrium. RV=Right ventricle. LV=Left ventricle. DD=Double density. LAA=Left atrial appendage. N=Normal. +=Enlarged or increased. ±=Doubtfully enlarged. Prom.=Prominent.

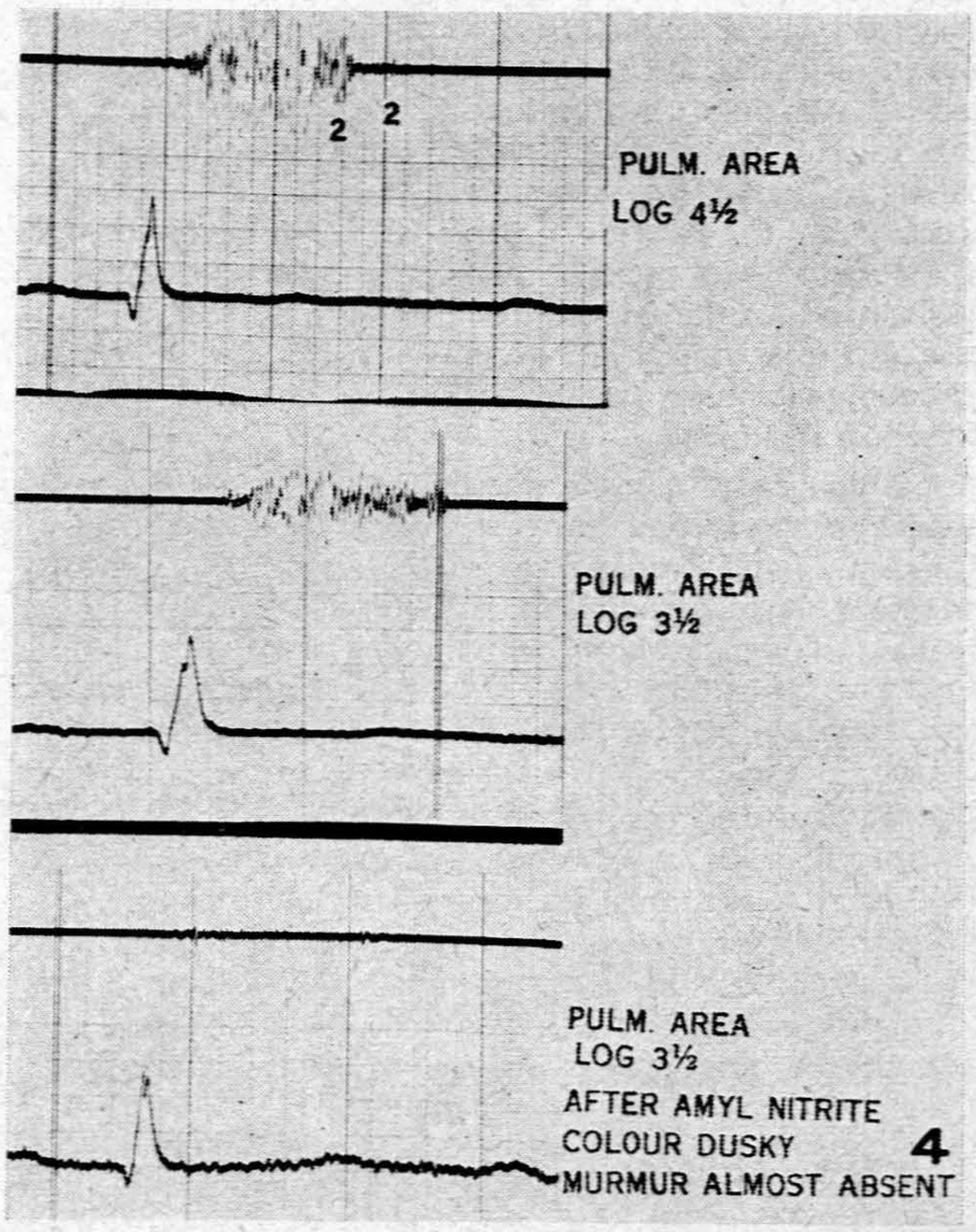

Fig. 4. Phonocardiogram showing marked diminution of ejection systolic murmur after inhalation of amyl nitrite.

pulmonary incompetence murmur disappeared, the systolic murmur became louder in early systole (Fig. 5).

X-Ray features are summarized in Table III. The cardiothoracic ratio was 50% in 4 patients, 51% in 1 case and 58% in 1 case. The pulmonary artery segment was prominent in 2 cases. The lung vasculature was increased in 4 patients, doubtfully increased in 1 and normal in 1. Right atrial enlargement was noted in 4 patients and left atrial enlargement in 3. The right ventricle was enlarged in all 6 and the

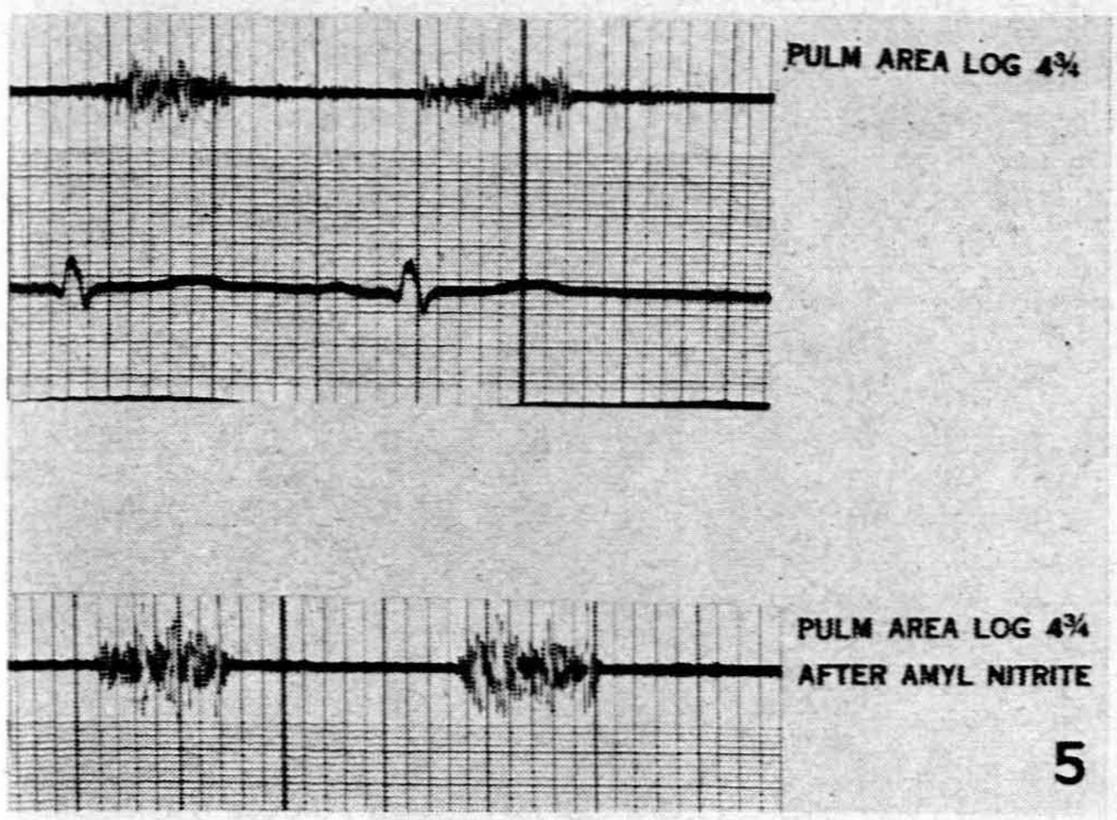

Fig. 5. Phonocardiogram showing increased intensity of early vibrations of systolic murmur after amyl nitrite.

left in 3 patients. The aortic arch was prominent in 3, and left-sided in all (Figs. 6 and 7).

Haemodynamic data are tabulated in Table IV. Cardiac catheterization showed equalization or near equalization of systolic pressures in the right ventricle and systemic artery in all cases. The brachial artery saturation was normal in case 3 (97%) and case 6 (90%) at the altitude of 6,000 feet, and 88% in case 5. Unfortunately the study in case 2 was completed during a syncopal attack. In cases 1 and 4 the patients developed mild clinical cyanosis during the procedure and hence their brachial artery saturations were decreased to 85% and 82% respectively. A pulmonary systolic gradient was demonstrated in all cases, being at valvular level in 2 cases, at infundibular level in 3 cases, and valvular and infundibular in 1 case. The pulmonary-artery pressure was elevated, despite the presence of pulmonary stenosis, in 4 patients, and in one of these the pulmonary-artery pressure was 25/5 mm. Hg despite its recording during an unconscious spell. The mean right atrial pressure was elevated in 3 cases and normal in 3. 'Pulmonary capillary pressure' was elevated in 1 of 3 patients where a satisfactory wedge tracing could be obtained.

Significant left-to-right shunts were present in 5 cases and possibly in the 6th (case 2), where a pulmonary artery sample measured 70·5% oxygen saturation before the syncopal spell and 41% during the spell. Right-to-left shunts were present in 4 cases during catheterization.

DISCUSSION

In 1954 Wood *et al.*[7] noted that in a series of 80 cases of tetralogy 10 patients were acyanotic at rest. The clinical features were similar to those of Roger's disease. However, effort tolerance was reduced in all cases and 4 squatted when breathless. The heart was quiet in its action and the jugular venous pressure was not raised. The pulmonary second sound was single in all cases but one. The electrocardiogram was normal in 3. At cardiac catheterization the right ventricular systolic pressure equalled that in the brachial artery or aorta. The pulmonary-artery pressure was normal in 3 and low in the remainder. The shunting of blood was negligible in 3, bidirectional in 1, with slight right-to-left shunting in 5 and slight left-to-right in 1.

Rowe *et al.*[8] described 4 infants with the clinical features of ventricular septal defect in whom further studies suggested a diagnosis of tetralogy of Fallot. The main symptoms were failure to thrive and frequent lower-respiratory-tract infections. All had systolic murmurs localized to the lower left

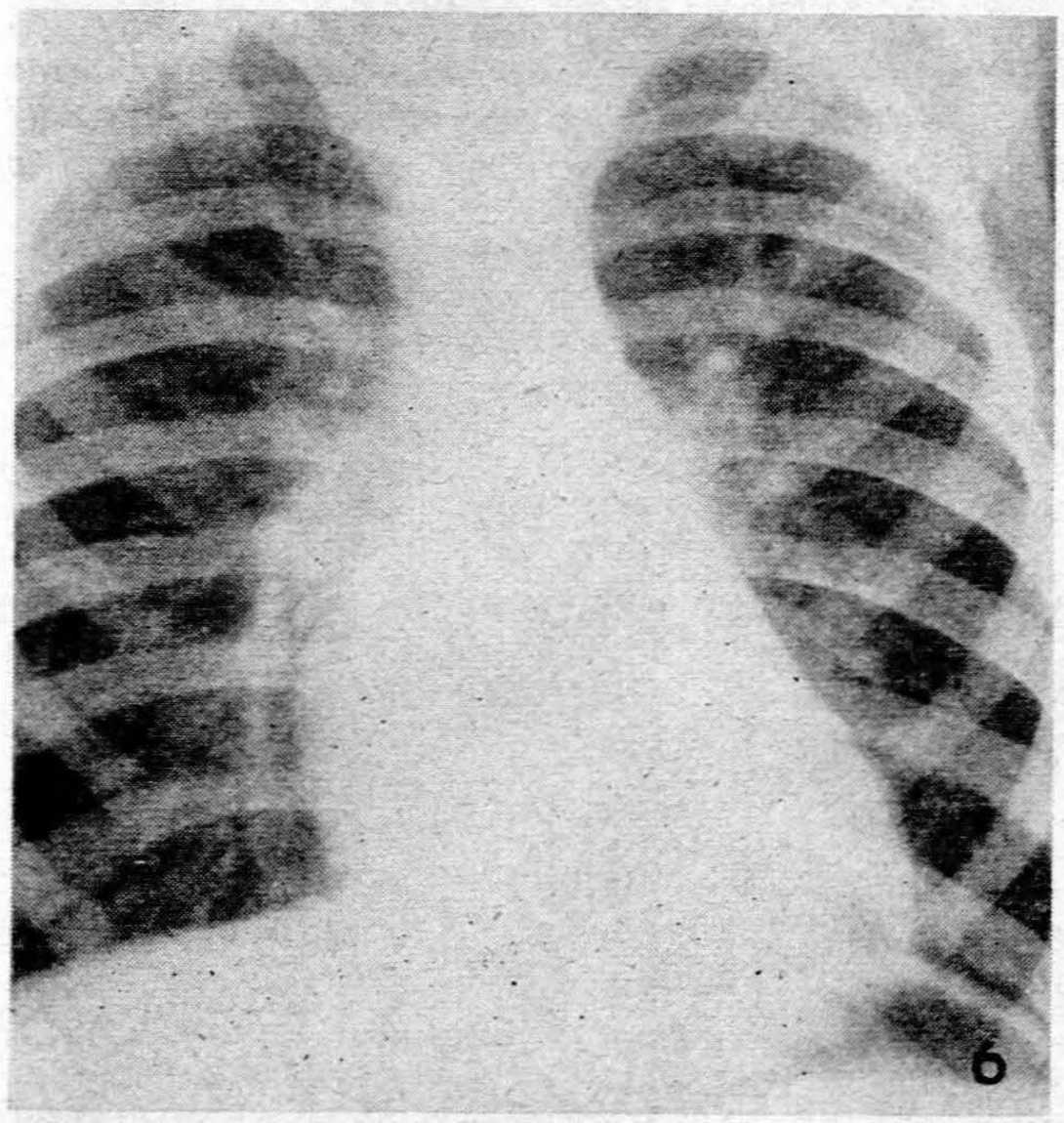

Fig. 6. Radiograph showing right and left ventricular enlargement, prominent pulmonary artery and prominent lung vascularity.

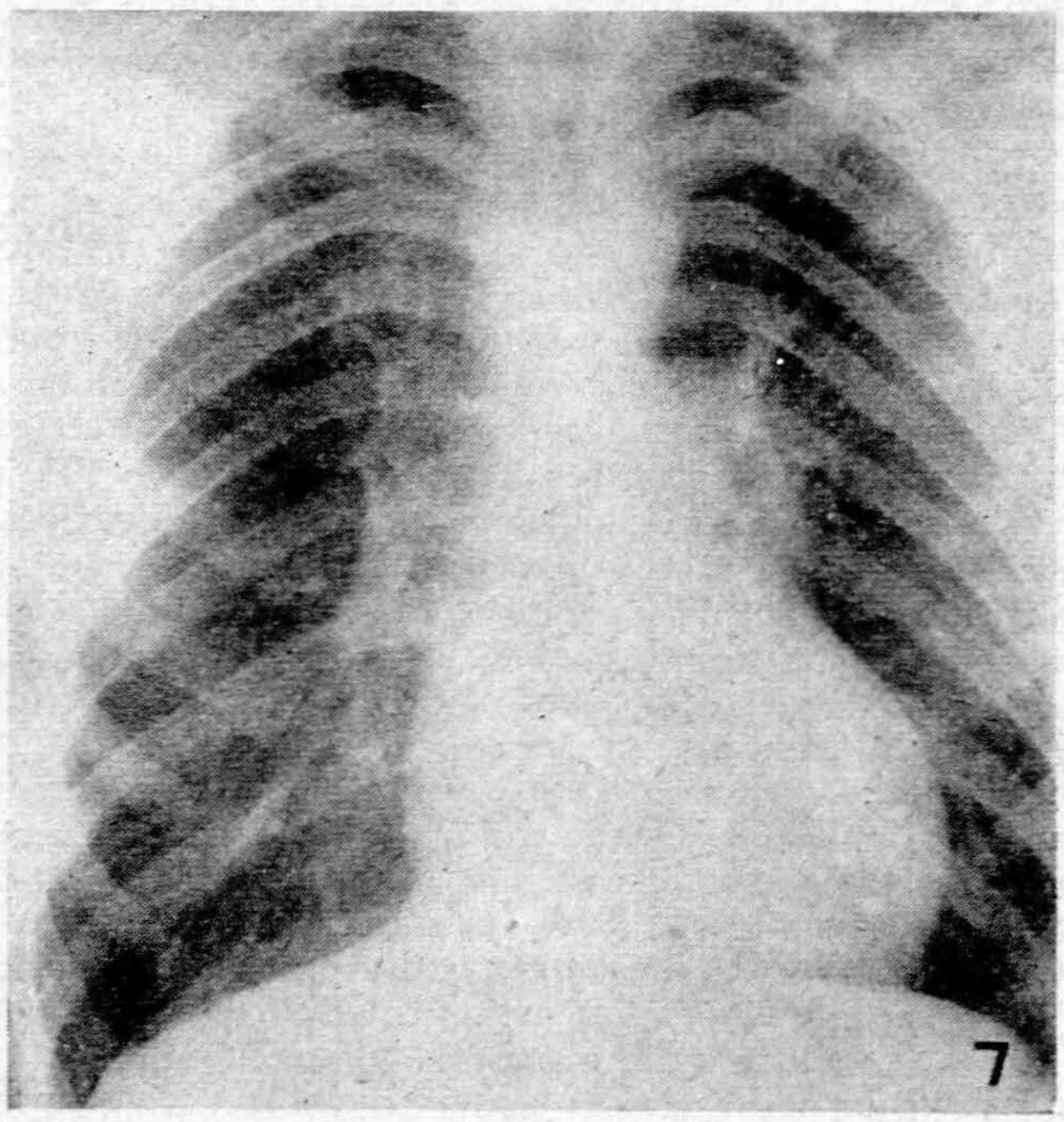

Fig. 7. Radiograph showing right ventricular enlargement, prominent pulmonary arteries and high aortic arch.

TABLE IV. HAEMODYNAMIC DATA

Case No.	Pressure (mm. Hg.)						Oxygen saturation (vols.%)				Flow (litres/square metre/minute)			
	WPA	*Pulm. Art.*	*RV Outflow*	*RV Inflow*	*Brach. Art.*	*Rt. Atrium*	*SVC*	*RV*	*Pulm. Art.*	*Brach. Art.*	*Systemic*	*Pulm. Art.*	*L—R Shunt*	*R—L Shunt*
1	8/4	44/24	75/0	75/0	75/45	m=2	10·27	10·27	11·29	13·6 (85%)	4·6	6·6	2·0	1·3
2	—	25/2	28/2	88/2	85/40	m=6			*11·25 †6·4	†7·1 (52·5%)	—	—	—	—
3	—	45/25	45/3	90/8	90/70	m=5	11·76	13·8	13·8	16·57 (97%)	2·66	5·0	2·34	Nil
4	m=15	34/20	80/5	80/5	80/50	13/8 m=10	12	15/2	14	16·2 (82%)	5·1	9·7	4·6	0·68
5	—	38/33	38/15	85/12	85/63	15/9 m=13	12·28	12·4	13·8	16·62 (88%)	4·4	6·6	2·2	0·76
6	15/5 m=8	30/5	50/0	100/0	100/65	m=3	12·2	14·4	14·4	16·2 (90%)	4	5·8	1·8	Nil

WPA=Wedged pulmonary artery. Pulm. Art.=Pulmonary artery. RV=Right ventricle. Brach. Art.=Brachial artery. Rt.=Right. SVS=Superior vena cava. L—R=Left to right. R—L=Right to left. m=Mean pressure (electronically integrated). *Specimen obtained before the development of a syncopal spell. † Specimen obtained during a syncopal spell.

sternal border. The pulmonary second sound was split in 2 cases. X-ray showed slight to moderate cardiomegaly and pulmonary plethora in all and a right aortic arch in 1. The ECG showed a normal axis in 2 and combined ventricular hypertrophy in all. Cardiac catheterization showed systemic systolic presures in the right ventricle and large left-to-right shunts. In one case pulmonary incompetence was present during life and autopsy showed a rudimentary pulmonary valve.

Bashour and Winchell[9] described 3 cases of Fallot's tetralogy with a preponderant left-to-right shunt at rest. They noted that the shunt sometimes reversed with exercise.

Calazel *et al.*[10] described abnormally well developed pulmonary vascularization in certain cases of Fallot's tetralogy. They suggested that in some tetrads the ventricular septal defect was more important than the pulmonary stenosis.

In 1957 McCord *et al.*[11] described 5 varieties of Fallot's tetralogy. Type 3—the mild tetrad—was characterized by the absence of cyanosis and minimal symptoms. In this, 7 patients were included, but in 3 the left ventricular systolic pressure exceeded that of the right ventricle. This latter group should not, by definition, be included in a group of tetrads. The clinical findings, radiological features and ECG tracings were similar to those described previously.

The cases in the present series are similar to those described in the literature. The pulmonary stenosis is moderate in all cases, the pulmonary-artery pressure being normal or elevated in the majority. The left-to-right shunt at the ventricular level predominates, and in some cases a small right-to-left shunt may be present. The separation of this type of tetralogy from the 'low' ventricular septal defect with moderate pulmonic stenosis and left-to-right shunt may be impossible if the systolic pressure in the aorta or systemic artery is equal to the right ventricular systolic pressure. Clinically, however, the tetrad variety has either a single pulmonary second sound or, more frequently, splitting of the second sound with either a decrease in intensity of the pulmonary component or both pulmonary and aortic elements equal in intensity.

The patients with ventricular septal defect and pulmonary stenosis usually show a split second sound with both components equal. Squatting and syncopal attacks probably only occur in the tetrad variety. The production of cyanotic attacks with a decrease in pulmonary systolic murmur and some decrease in pulmonary-artery pressure during cardiac catheterization occurs, as far as we know, only in the tetralogy variety. In one of our cases an unconscious or syncopal spell with complete absence of the pulmonary systolic murmur, lasting $2\frac{1}{2}$ hours, was induced by cardiac catheterization.[2] A striking decrease in intensity of the systolic murmur after inhalation of amyl nitrite is typical of tetrads[6] (Fig. 4). However, this finding is not, in our experience, invariable and case 4, in whom a tetralogy was proved at operation, showed an increase in intensity of the murmur on several occasions after inhaling amyl nitrite (Fig. 5).

The acyanotic variety of Fallot's is a definite entity. Its clinical features, X-ray findings, ECG abnormalities, and haemodynamic findings, have been detailed. The absence of cyanosis, in spite of an 'overriding' aorta, is dependent in

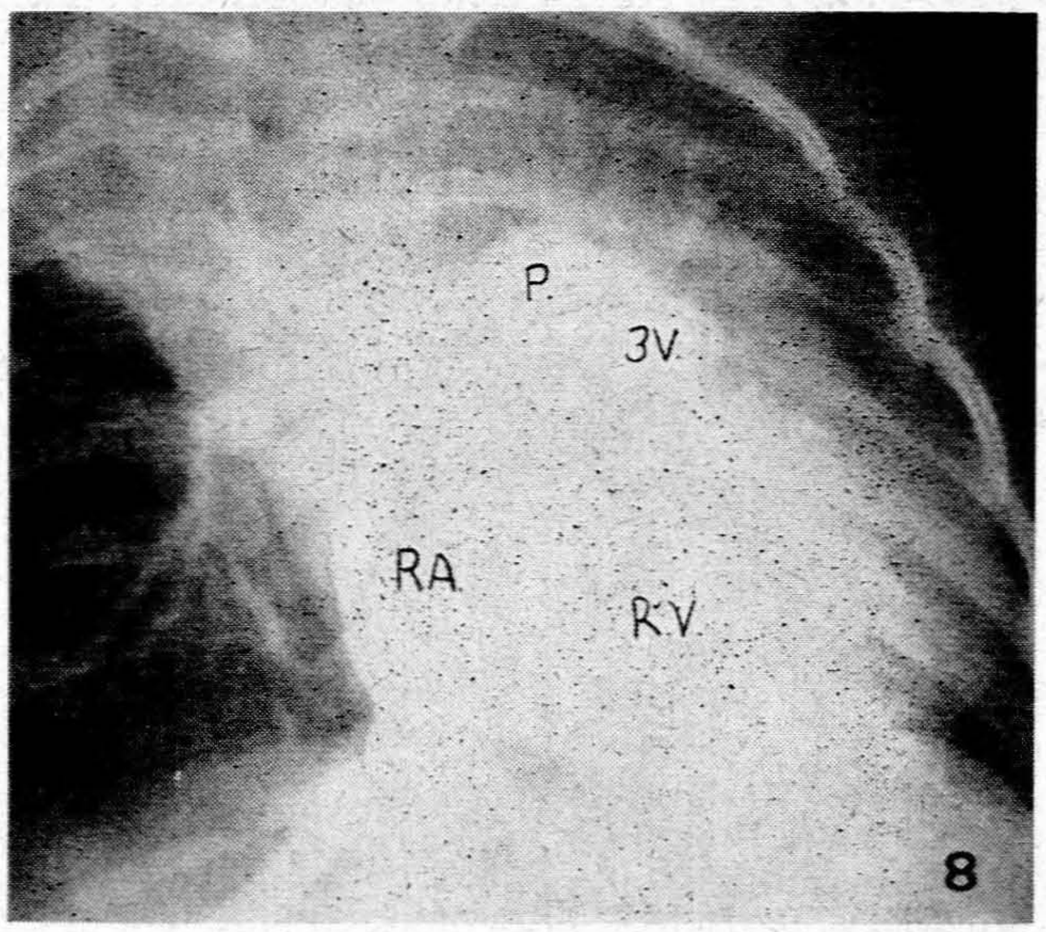

Fig. 8. Angiocardiogram showing infundibular stenosis, but no filling of the 'overriding' aorta (3V=infundibular chamber).

these cases on the severity of the pulmonary stenosis. If the resistance offered by the pulmonary outflow tract, or valve, is lower than systemic resistance, blood will shunt left-to-right only. We have recently seen an infant aged 8 months who is not cyanosed at rest but has frequent cyanotic and syncopal attacks. Cardiac catheterization revealed infundibular stenosis, ventricular septal defect with left-to-right shunt, and equalization of the right ventricular and systemic blood pressure. Angiocardiography demonstrated an infundibular chamber and large pulmonary arteries. The aorta did not fill simultaneously with the pulmonary artery (Fig. 8 and 9) despite its 'overriding' the ventricular septal defect. After

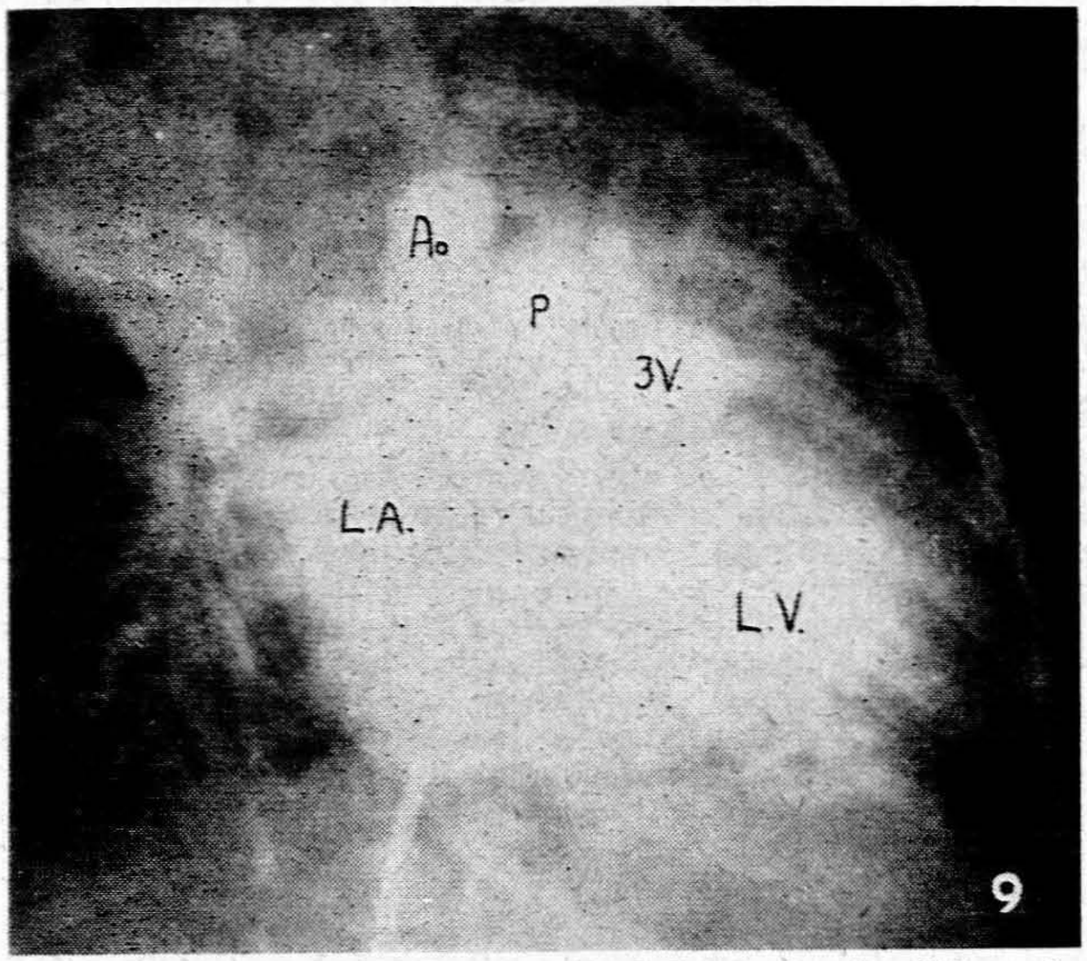

Fig. 9. Same case as Fig. 8, 3 seconds later, showing filling of aorta from left ventricle.

the anaesthetic was terminated the baby developed a severe 'blue spell', which persisted for about 4 hours.

We have previously shown[1,2] that the degree of obstruction to pulmonary flow may increase spontaneously and strikingly after cardiac catheterization. It is believed that this situation, with the production of cyanotic or unconscious spells, may make this disease dangerous. Furthermore, these patients are all symptomatic. Patients with spells rarely reach adulthood. It is felt, therefore, that the prognosis is poor, and, with the progress of open-heart surgery, we believe that corrective surgery should be advised in all cases. To date 4 of our patients have undergone corrective surgery and there has been 1 death amongst them.

SUMMARY

1. The significant components of the acyanotic variety of Fallot's tetrad are described. They comprise equalization of systolic pressures in both right and left ventricles, a ventricular septal defect, and moderate pulmonic stenosis.

2. All cases have dyspnoea on exertion with loud systolic murmurs in the pulmonary area or lower left sternal border. The pulmonary second sound is usually split, with decreased intensity of the pulmonary component. In some cases it is single.

3. The ECG shows right ventricular hypertrophy and may show left ventricular hypertrophy as well.

4. X-ray examination shows normal or slight cardiomegaly, with normal or increased pulmonary vasculature. A right aortic arch has been reported in the literature in only 1 instance and was not seen in our series.

5. Cardiac catheterization studies reveal equalization of right ventricle and aortic pressures. A left-to-right shunt is demonstrated in the majority of cases. Systemic arterial saturation is usually normal except during cyanotic or unconscious spells. Cardiac catheterization has induced cyanotic and unconscious spells.

6. The possibility exists of sudden death following on unconscious spells despite the presence of a left-to-right shunt at ventricular level. Corrective surgery is recommended.

We thank Dr. J. Meyer and Dr. W. Scott for their assistance at cardiac catheterizations. We are indebted to the photographic section of the Department of Medicine of the University of the Witwatersrand for photographic reproductions. We thank Mr. H. I. Goldman of the CSIR Cardio-pulmonary Unit, Johannesburg General Hospital, for blood-oxygen analyses.

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