CONGENITAL HEART DISEASE IN THE PAEDIATRIC AGE-GROUP

A Thesis

presented for the degree of

Doctor of Medicine

by

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October 1954.

ACKNOWLEDGEMENTS

The information embodied in this thesis was acquired during the tenure of an Exchange Scholarship between the Universities of Edinburgh and Wisconsin. The generosity of the latter institution made possible a further stay as a Research Fellow in Pediatric Cardiology.

The author is indebted to Professor John E. Gonce, and Drs. Waisman and McDonough of the Department of Pediatrics, University of Wisconsin, for permission to study cases in their care. The cardiac catheterization data were obtained under the supervision of Dr. Charles W. Crumpton, of the Cardiovascular Laboratory, University of Wisconsin; much is due to his interest and encouragement at all stages. Dr. Lester W. Paul, of the Department of Radiology, gave permission to reproduce the X-rays. The pathological reports were provided by Dr. Angevine of the Department of Pathology, University of Wisconsin.

SUBJECT MATTER

Section 1

HISTORICAL REVIEW AND SURVEY OF AETIOLOGICAL BACKGROUND

'The heart of animals is the foundation of their life, the sovereign of everything within them, the sun of their microcosm, that upon which all growth depends, from which all power proceeds.'

-- William Harvey --

The material in this thesis was drawn from the pediatric practice of the University Hospitals, University of Wisconsin. It represents those cases - almost all seen personally - who were examined as inpatients, or seen at follow up in the Out-Patient Department. Not all types of congenital heart disease are represented, and the series was not selected to any great extent, except in so far as the facilities here available undoubtedly attracted more of this type of patient than an ordinary hospital. The majority of cases were of the acyanotic or "cyanosis tardive" type; most were referred at an early age - a tribute to the abilities of the local practitioners, and the value of a routine examination at the age of six weeks.

The study is confined to the paediatric age-group, the majority of cases being less than 5 years of age. Thus emphasis will be placed on the particular problems of the earlier years, especially with regard to growth, initial symptoms, and the clinical state in earlier life. Full details of the age grouping and routine and specialized methods of investigation will be given below.

The purpose primarily is to elucidate the clinical picture in the younger age groups, to examine the evidence for the application to the pediatric age group of diagnostic criteria originally derived from the study of adults and to determine the relative value of certain expensive and specialized methods of investigation.

There can be no doubt that the possibility of surgical treatment for certain types of inborn heart disease has heralded a Renaissance in the study of these conditions; the front of surgical attack widens every day, but suitable treatment depends initially on the discovery of cases, and an exactitude of diagnosis previously considered valueless, or pointing only to medical pedantry. Laubry and Pezzi (1921), speaking of studies on adults, point out the ubiquity of the problem, however it is

primarily the paediatricians' responsibility to diagnose, and, equally important, to decide the best time for appropriate surgery. This is not easy, even with the most modern methods, as the cases below will show but it is hoped that the record of experiences with these children will be of interest, and perhaps, in a small way, of some value.

Historical

As in all fields of knowledge, we are the heirs of the past. This is true of the study of congenital heart disease, involving as it does embryology, pathology, and physiology in a unique triad. Such a dramatic picture as cyanosis, the symptom 'par excellence' of congenital heart disease did not escape the attention of the Ancients; however its relationship to inborn cardiac defect was not early appreciated, even in the Hippocratic corpus, although cases with cyanosis are described. Doubtless the absence of post-mortem examination, and the almost religious belief in the immunity of the human heart from disease explains this finding. A similar attitude of mind explains the lack of reference to congenital heart disease in the works of the mediaeval writers such as Galen, though the physiology of that time postulated the presence of interventricular communication as a 'sine qua non' for the circulation of the blood.

This Galenical form of thought was not seriously challenged until some 13 centuries later, when the religious and superstitious objections to human dissection had been overcome. This coincided with the rise of the Renaissance schools of medicine in Italy. By the end of the sixteenth century, the anatomy of the foetus had been partially explored, and such familiar terms as the 'ductus Botalli' and foramen ovale bore witness to the fact that the systematic study of congenital heart disease had begun.

From this period until modern times, the emphasis was laid on anatomical, and eventually, pathological changes in such cases; the conception of heart disease as a function of disturbed physiology is a recent event. By the 18th century, Jean Baptiste de Senac had devoted

2 chapters of his 'Traite de la structure du coeur, de son action et ses maladies' to inborn heart disease, and the great pathologist Morgagni had given some clinical, and considerable anatomical detail of such cases, including one of pulmonary stenosis with patent foramen ovale. Sporadic case reports occurred, but the relationship of cyanosis to congenital heart disease was now well established, and the early 19th century was familiar with such terms as 'maladie blue, 'Morbus caeruleus,' and 'cyanopathia', the exact name varying apparently with the author's leaning towards a Romantic or Humanistic nomenclature.

By 1858, there were many isolated reports in the 'Transactions of the Pathological society of London', and in that year Peacock published the first Edition of his classical 'Malformations of the Heart', with full clinical and pathological descriptions, and with one of the earliest chapters concerning the treatment of such unfortunates. At almost the same time (1855) Rokitansky had published his study of septal defects and given a masterly account of the pathological anatomy together with an explanation, mainly on embryological grounds, of their genesis. This latter point was fully correlated with human and comparative embryology by the late Sir Arthur Keith in the Hunterian Lectures for 1909. These two authors in essence laid the foundations for the proper understanding of the relationship of such defects to the development of the human heart.

In the earlier years of this century, an Edinburgh graduate, Maude Abbott, took the first steps in systematizing the types of congenital heart disease, and wrote widely on the subject; she insisted on absolute diagnosis at post-mortem, and correlated the clinical findings with those at autopsy. Her contribution to paediatrics cannot be overestimated, and Helen Taussig, who first suggested the possibility of surgical treatment of these afflicted children, admits her debt to Abbott in her celebrated "Congenital Malformations of the Heart", an exhaustive study of the subject based on the Abbott approach, but including also the modern methods of investigation whose value she was among the first to appreciate and place

on a firm basis; to her, and to Alfred Blalock we owe the conception and execution of a planned method of surgical relief. Their methods were adopted and modified by Potts, and recently a British surgeon, Brock, has married physiology and surgery in his direct attack on the stenotic pulmonary valve. It is sufficiently obvious that the danger of these operations demands as much information as possible, and to this end the physiological investigation of cardiac catheterization as introduced by Cournand, and developed by Bing, McMichael and others, has become increasingly of value. Anatomically, the use of angiocardiography, and retro-grade aortography (Dotter and Steinberg 1951) have shown their value.

In spite of these additions to the diagnostic acumen, there is still much to be learned regarding the natural history of these conditions, since therapeutic nihilism has until recently, given little stimulus to the recording of valuable data such as the death rate, cause of death, incidence within the normal community and so on. There is still no doubt that the general practitioner and paediatrician working without benefit of specialized methods of investigation, can still contribute much to the understanding of congenital heart disease.

Aetiology

The aetiology of congenital heart disease is that of any inborn defect, tho' historically an "embryogenic" or infectious cause was postulated. The latter theory was supported by such protagonists as Morgagni, Peacock, and Cruvheilier and the former - and earliest - concept was originally that of de Senac; who considered lesions to be 'fautes de la nature formatrice'. Meckel (1812) by comparing the anatomy of congenital defects with the normal state of lower animals, admitted "an arrest in the evolutionary process of the heart"; Rokitansky (1855) and Keith (1909) completed the association of the lesions with embryology.

The theory of foetal endocarditis still has its supporters, tho'

seldom now is it brought forward, and many of the cases described as such may well have fitted into the lesion now known as 'fibro-elastosis'; however this tends to beg the question, since the change of name does not explain the nature or cause of this particular condition. The evidence against the infective theory is well tabulated by Laubry and Pezzi (1921), who conclude that it is untenable; they warn of the dangers of confusing secondary inflammation with a pre-existing lesion, and quote such an authority as Rokitansky (1855) to show that many of the lesions previously thought to be infective, were in fact, mechanical in origin.

It is not then possible to discuss congenital heart disease without a preliminary consideration of the aetiology of inborn defects in general; an admirable review of the subject given by Warkany (1949), who points out that it has been considered that all inborn defects are genetic in origin, and therefore hereditary, he gives valid reasons for believing that this is not so. He emphasizes the necessity for caution in ascribing human defects to the known modes of inheritance, following the study of short and isolated human pedigrees.

In general, it is possible to show that two sets of factors may operate in the appearance of inborn defects. These are genetic and environmental. The former are considered first.

The basic facts that an inheritance may be by dominant or recessive gives is well established. Dominant inheritance will occur whether a persons is genetically heterozygous or homozygous, and defects will appear when mating with a normal occurs. This will occur in some 50% of the offspring; occasionally however the condition may not show itself, i.e. there is 'reduced expressivity' - the genetic inheritance is present but the pathological state is covert. The best example of this is spherocytic haemolytic jaundice. If dominant inheritance occurs, then a strong family history will be present; this is relatively rarely found in congenital heart disease though family pedigrees for such conditions as patent ductus are found in the literature.

The other mode of inheritance is by 'recessive' genetic factors; thus a person who appears normal, but is heterozygous for a recessive gene, will produce normal offspring with a mate who has normal genes for the trait in question; however if he mates with another who is heterozygous also, 25% of the offspring will be homozygous, and manifest the pathological trait. Phenotypically 75% of the offspring will be normal, but 50% will be heterozygous like the parents, and act as carriers (like the homozygous children) of the congenital defect.

If the abnormal gene is rare, as in congenital heart disease, the chances of two heterozygous carriers mating will be rare, unless they marry within the family circle. So there should theoretically be a higher incidence of manifest pathological traits in the offspring of consanguineous marriage, and conversely this type of lesion will be more common in the parents of those showing a rare trait than in the population at large. Finally, it should be noted that the offspring of individuals who have an abnormal recessive trait will all be abnormal whereas a homozygous individual showing the trait who mates with a genotypically normal, will produce seemingly normal carriers of the trait only.

Many factors have been incriminated as non-genetic causes of congenital defect. These include, faulty implantation of the ovum, or abnormalities of chorion. Ectopic pregnancies commonly result in malformed foeti, and Mall (1908) noted that a large number of his obstetric cases of defect showed congenital anomalies.

Vitamin deficiencies in the parents has been shown to produce defects in animals, and lack of vitamin A was shown by Hale (1933), to cause the appearance of cleft palate, anophthalmia, and other lesions. Warkany and Nelson (1941), similarly demonstrated that lack of riboflavin might cause congenital anomalies. Mineral deficiency has been shown to be of etiological importance. Persistent patency of the foramen ovale as a result of Iodine lack was noted by Smith (1917).

Actinic factors are well recognized as precursors of inborn anomaly; Goldstein and Murphy (1929), review the evidence for this and point out the dangers of irradiation during pregnancy. The more recent dangers of the aftermath of atomic radiation in the production of defects is noted by Plummer (1952).

Chemical as well as physical factors may operate in the genesis of congenital defect. Thus Selenium has been observed to induce deformities in fowls (Franke and Tully 1936).

Few of these factors can be adduced with certainty as the cause of inborn deformity in humans, except perhaps of Iodine lack in the causation of some cases of cretinism. More definite perhaps, is the role of maternal infection, especially by rubella or toxoplasmosis. The latter has so far shown no relationship to congenital deformities of the heart, and will be ignored. Rubella was shown to cause defects, by Gregg in 1942, and his conclusions have been amplified and confirmed by many others since then. Many cases of acyanotic congenital heart disease have been shown to be associated with maternal rubella. Apparently the infection strikes at the heart in the relative stage of development at which it is. Thus it would appear that after the stage of embryonic organization is past, maternal infection is of little importance. The role of other maternal infections of pregnancy has so far been inconclusive, though mumps has resulted in congenital heart defect (Swan et al. 1943).

It has been already noted above that obstetric abnormalities, producing an inferior environment, may be associated with congenital defect. Thus Murphy showed that a history of relative sterility was sometimes present in the period before malformed children were born. Maternal diabetes has also been implicated (Lawrence and Oakley 1942).

In this investigation, certain features were particularly noted, in order to explore some of the factors involved. These were: a history of abnormalities of a hereditary nature in the parents and family tree;

history of similar cardiac or other malformations in siblings of the affected child, and evidence of consanguineous marriage.

Environment was checked by a short social history, review of the pregnancy for obstetric troubles or infections (especially of viral origin). The maternal age and pregnancy position of the affected child were noted.

In addition to the genetic factors noted in the first section above, these children were carefully examined for evidence of other congenital defects, since this would tend to support a genetic aetiology for the cardiac defect. This however should be interpreted with caution, since multiple congenital anomalies may be found after a disturbance of the foetal environment by non-genetic factors, such as rubella or maternal diabetes.

The findings concerned with the genetic factors will be considered first.

The genetic factors

Some of these have been briefly discussed in the preceding section. Attention from this point of view will now be given to this series.

Consanguinity

This was carefully enquired for. In one instance an incestuous union had occurred. This resulted (case 110) in a case of atrial septal defect. The low incidence parallels the findings of Campbell (1949), and would tend to suggest that congenital heart disease does not as a rule exist as a recessive. Malpas (1937) suggests that it is unusual in other congenital defects also. Cockayne (1938) has however shown that congenital heart disease with dextrocardia and situs inversus might be recessive. McKeown (1953) and his collaborators have confirmed this opinion, while noting a low incidence of consanguineous marriage in their series.

While Roesler's (1928) series had 10% of consanguineous unions, the impression remains that in general this is a factor of low import in the causation of congenital heart disease.

Familial defects

The occurrence of cardiac or other congenital defects within the family might be interpreted as support for a genetic aetiology. McKeown et al. (1953), have shown that the incidence of congenital heart disease is higher in siblings born after a previously affected child. They did not consider the incidence of other inborn defects to be significant. Campbell (1949) came to a similar conclusion.

Routine questioning in this series suggested that associated defects (mostly non-cardiac) occurred in 9.8% of the near relatives of children here studied. This figure agrees well with that given by Dogramaci and Green (1947), who describe an incidence of 10%.

The table gives the details of the lesion and relationship. The agreement of most authors suggests that the incidence of defects within

the family is suggestive of a genetic factor in some cases.

Since the completion of the statistics for this series the author has heard of two identical cases of tricuspid atresia with pulmonary stenosis in the first and second born of a young mother. The diagnoses were confirmed at autopsy.

Sex incidence

Haemophilia is the common example of a sex-linked congenital diathesis. A predominant sexual predilection may therefore be evidence in favour of a genetic determination. No significant association in this series could be found. The incidence, compared with that of other authors is given in the table. (2)

Associated defects

Abbott (1937) in her celebrated review of a thousand cases of congenital heart disease noted that 18.8% had associated non-cardiac malformation. Irvine-Jones (1926) found an incidence of 54%.

In this series 71 of 200 cases had associated defects - many of them serious. The details are given in the table. The high incidence of associated malformations may perhaps be suggestive of some genetic factor. However in two of the cases described here the pregnancy was complicated by rubella.

A comparison of the incidence of associated malformations for various series is given in the table. (3)

Environmental factors

Maternal age

In 1909, Shuttleworth associated advanced maternal age with mongolism; Ingalls (1947) gave modern support to this concept. In the more general sense, Landtman (1948) considered that advanced maternal age had a positive correlation with a variety of congenital defects.

In this series, an effort was made to examine this point. The maternal age of the birth of the affected child was recorded. Comparison

was made with a control series made up of all live-births, in the state of Wisconsin in 1952. The figures were drawn from the files of the State Board of Health kindly supplied by Dr. Amy Hunter. The results are given in the table opposite, together with a statistical analysis of the difference found.

The results show that there is no definite statistical difference in the control and affected groups as far as maternal age is concerned. It is noted that a deficit of mothers of congenital heart cases occurs in the age group 25-34. The results closely parallel those of MacMahon (1952) who was unable to trace any association with maternal age in the aetiology of congenital cardiac flaw. It is perhaps noteworthy that this paper also there was significant diminution in the numbers in age-group 23-27.

Parity

In considering congenital malformations in general, Murphy and Mazer (1935) thought that the incidence was higher in the later birth-ranks. The association of Mongolism with last births was observed by Shuttleworth (1909).

In regard to congenital cardiac flaws, Still in 1927 found 34.3% to be first born as compared with a control incidence of 18.5%. Lamy and Schweisguth (1950), could find no association. In the series studied here, the position of the affected child was recorded. In assessing this, previous abortions were not considered. The results were compared with a control series made up of all live births in the State of Wisconsin for 1952. The pregnancy position is required on the birth certificate in this state. The figures are as given by the State Bureau of Health.

The results are given in the table. It will be seen that there is no statistical evidence of any constant relationship between parity and inborn cardiac defect. Again however an apparently significant deficiency of 3rd births occur in this series.

It is felt that there is no evidence then of an association with parity.

The close parallel between this series and that of MacMahon is very striking. The distribution of Mongols in this series was even among the parity groups presented, and made no statistical difference to the results already presented. The opposite results observed by Still (1927) and Landtman (1948) are possibly due to the control series used by these authors.

Prenatal factors

Many of these have already been mentioned in the introduction to this section. An effort was made to acquire certain information concerning the mother's condition during pregnancy. Attention was paid particularly to events and abnormalities during the first trimester when foetal organization is at is height. It would obviously be better to follow mothers during pregnancy so that all abnormalities at this time could be accurately associated with the outcome at term. The disadvantage then in retrospective questioning should be borne in mind while evaluating the results given here.

Nutritional status

A poor maternal diet has been correlated with a high sterility and abortion rate (Gilman et al 1948). They adduced that the absorbing surface of the intestines was secondarily damaged and thus "abnormal products" entered the circulation. Though a poor diet may affect foetal length and weight (Smith 1947), there is as yet no definite evidence that malnutrition of the mother predisposes to congenital defects.

The mothers in this series were fairly representative of the various social classes. In no instance was there evidence of a diet insufficient either in caloric or vitamin content.

Uterine haemorrhage in the early months

Interest in this as a factor was stimulated by the observations of Landtman (1948) and Ingalls (1947). They found a significantly higher incidence of early pregnancy haemorrhage in a study of general malformations and mongolism respectively.

Control series are difficult to come by, and therefore data was collected for a series of 200 children who were considered free of congenital defect. Approximately the same numbers fell in the same age groups for each series. Thus it was thought that defect of maternal memory would be equal in each group.

By this method, two mothers (1%) of the control group had bleeding in the early months; six mothers (3.25%) in a group of 185 congenital heart cases had similar troubles. The difference (2.25%) just fails to be twice the standard error (1.46). Therefore it cannot be said with confidence that uterine haemorrhage in the early months has a significant association with resultant congenital cardiac disease.

Maternal infections

It has already been noted that maternal rubella and toxoplasmosis may result in foetal malformation. Other conditions in pregnancy have also been implicated. These include mumps (Swan et al 1943) and measles (American Academy of Pediatrics 1948). The influence of pregnancy influenza in causing abortion and still birth has been commented upon by Bland (1919), and two cases of the same disease (at 2 months gestation) resulted in mongolism in the series of Ingalls and Davies (1947). Dogramaci and Greene (1947) feel however that scarlatina, mumps and rubella do not constantly produce anomalies even if they occur in early pregnancy.

In this series the incidence of such pregnancy abnormalities was compared with a control group of 200 normal children of the same age distribution as the congenital heart group. Similar pregnancy histories were obtained. The results are shown in the table. Only infections occurring in the first four months were recorded. There is a significant increase of infections in the mothers of the congenital heart series, the difference exceeding twice the standard error. This is due to some extent to the number of pregnancies complicated by rubella in the affected group. It is thought unlikely that the other diseases recorded do have a specific influence. Fox and his collaborators (1948)

specifically exclude chicken pox, mumps or measles in the first trimester of pregnancy as a constant factor. It is also significant perhaps that no case of congenital defect followed maternal vaccination even in the early stage of pregnancy (Bellow et al 1949).

Maternal exposure to infectious disease

Bela Schick (1949) notes that the foetus may be affected by small pox even where the mother is immune. Lundstrom (1952) in studying an outbreak of rubella showed that of mothers previously immune to rubella, a significant proportion of those exposed to the disease would have an increased incidence of stillbirth, neonatal mortality and foetal malformation. Warkany (1947) records a case where the mother was exposed to rubella at the second month of gestation. She herself remained well, but her offspring was congenitally deformed.

The significance of these findings did not come to mind early enough to obtain data on the whole series here recorded. Only the last part (98 cases) of the congenital heart group, and 100 cases of the control group were questioned specifically on this point. It was difficult also to be certain if the mothers had in fact had rubella and were immune, since the patient's word had to be accepted on this point. The risk of exposure will vary greatly from season to season and naturally will be greater in those mothers who have children of school age who are liable to acquire the exanthemata. It was found that two of the 100 control cases had been exposed to measles; of the affected group (98), three had been exposed to rubella and two to measles. The difference in per cent incidence (see table) fails to be twice the standard error, and therefore is not statistically significant. In spite of the difficulties already mentioned, it would be valuable if more information on this point could be obtained.

Other conditions

No reliable information on the influence of pregnancy toxaemia could be obtained since the mother's word had to be taken on this point.

This is too unreliable a standard. Landtman (1948) found no relationship with pregnancy toxaemia in his series.

No exposure to x-rays, radium or noxious chemicals was reported in this series; there was no case of maternal diabetes.

Three children suffered from erythroblastosis foetalis in addition to congenital cardiac defect. The significance of this incidence is obscure though Javert (1942) found some 21% of a series of erythroblastosis foetalis to have associated congenital defects, only one of these cases however had a cardiac anomaly (ventricular septal defect).

Summary

The various complications of early pregnancy in the mothers of children with inborn heart disease are presented in the tables, together with a note of the cardiac lesions found. Excluding those merely exposed to infectious diseases, the incidence is 10.2% for the affected group, that for the control series was 5%. The difference (5.2%) is just twice the standard error (2.595%) and is regarded as significant. The one case of tetralogy of Fallot which followed undoubted rubella in early pregnancy is of some interest. The author has been unable to trace any other case of cyanotic cardiac defect following this disease.

Discussion

A review is offered of factors, genetic and enviromental which may cause congenital defects. A survey of the background of 200 cases of congenital heart disease is made. It is found that consanguinity does not in general bear a relationship. The incidence of other inborn defects in the congenital heart patient is high, as is the incidence of inborn pathology (usually non-cardiac) in the family tree. The sex incidence is approximately equal. Maternal age and parity do not have a statistically significant relationship to congenital heart disease.

Maternal nutrition during pregnancy was satisfactory in this

series. There was no case of actinic or chemical exposure in gestation. The incidence of bleeding in early pregnancy is higher in the mothers of congenitally affected children than in a control series, but this finding does not bear close statistical scrutiny. Infections in early pregnancy, especially rubella may cause inborn flaw of the heart. A suggestion is made that exposure to exanthemata in pregnant immune women may also be a factor. A case of cyanotic heart defect following rubella is reported.

Most noteworthy is the fact that most cases of congenital heart disease have an essentially normal background. No firm conclusion can be drawn from the literature or from this series as to the principal factors involved.

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Section 2

THE TETRALOGY OF FALLOT

THE TETRALOGY OF FALLOT

This condition, described by Fallot in 1888, but fully represented by Peacock (1866), is one of the commoner cyanotic inborn defects of childhood.

The work of Blalock and Taussig (1945), in the surgical relief of the condition, has stimulated a flood of papers on the clinical and therapeutic aspects of tetralogy.

Taussig (1947), has given a full description of the clinical features of the condition, has reviewed the pathology, and amplified the concepts of Abbott (1936).

Investigative methods by cardiac catheterization have been described by Bing et al. (1947), and Cournand (1949). Dotter and Steinberg (1951), have reviewed the use and limitations of angiocardiography.

A synthesis of clinical and special investigations, together with surgical treatment, has been given by Mannheimer (1949). Further advances in the surgical treatment of this and allied conditions have been made by Potts (1946), by anastomosis of the aorta and pulmonary artery; Brock (1948) has attacked the problem more directly by pulmonary valvotomy.

The material here discussed, consisted in 40 cases, 24 males, and 16 females, all of white ancestry. The age and sex range is seen in table 1; there is a slight preponderance of males, and most cases were in the age range of 1-5 years at the time of examination.

All cases were given a thorough work up, nearly all being admitted to hospital. In addition to the usual clinical examination, all cases had routine electrocardiography and x-ray studies. Some were studied by angiocardiography and cardiac catheterization. The summarized case reports are given in the appendix.

Symptomatology

Tabular methods are used to present this data, so that the reader

may extract details which are difficult to present in the context. The usual complaints in this condition are of course cyanosis and shortness of breath. The former is a dramatic symptom which generally attracts early attention, the latter, while usually obvious, may be missed by the mother of an only child - she feels that dyspnoea is normal for her baby. More detailed attention will now be given to each symptom.

Cyanosis

This is the manifestation of the circulation of reduced haemoglobin. In the tetralogy of Fallot it is due to the venous-arterial shunt consequent upon the ventricular septal defect and over-riding aorta; also involved is the impediment of the oxygenation of blood presented by the pulmonary stenosis (Taussig 1947).

As shown in table 2, it is a constant feature of this disease, though its true age of onset may vary considerably. In this series, analysis of the figures shows that 21 of the 40 cases presented with cyanosis at birth, and, at the other end of the scale, 5 cases showed no cyanosis until after the age of 2 years. In one, blueness appeared only at the age of 7 years. Case 148, is interesting in so far as "intense" cyanosis was noted during the first month of life, but this decreased steadily with the advance of years, tho' being still present on exertion at 8 years of age. Contemporaneously the symptom of squatting improved also. This child was thought to have a patent ductus arteriosus and arterio-venous fistula of the right lung in addition to the tetralogy. It is conceivable that a degree of pulmonary atelectasis may have contributed to the marked cyanosis in the first month of life; however the child was not seen at this hospital at that time, so no full explanation of this interesting fact is available.

As one would expect, the cyanosis is aggravated by exercise (see table 2). This occurred without exception in the cases here presented. Taussig (1947), echoing many other authorities says that the cyanosis is most obvious in the skin areas where the capillary supply is richest, i.e. the nail-beds, the face, nose, lips, and ears. The findings here

are in accordance with this statement. General cyanosis is of prognostic importance, this was noted in 6 cases (all infants), and was associated with a fatal outcome in five, and with congestive cardiac failure in the remaining child. It is probable that generalized cyanosis, at rest, reflects pulmonary atresia, or a severe degree of pulmonary stenosis. This was found in cases 157 and 171 for example in whom this symptom was present.

Dyspnoea

This, again due to impaired oxygenation of the blood and with the same cause as cyanosis, is a constant feature. Table 3 breaks this symptom down into, age of onset, whether present at rest or on exercise, gives the incidence of paroxysmal attacks, and relates the complaint to exercise tolerance. The latter is difficult to evaluate; in general, the degree of impairment must be assessed separately for infants, and for those children who are old enough to walk. In infancy the exercise tolerance was deemed normal if activity appropriate to the child's age produced no objective dyspnoea. It was considered moderately reduced if caused by moving about in bed, crawling, or hard crying. It was markedly reduced if bowel-movement, rolling over, or sitting up provoked severe dyspnoea.

In the older child, exact measurement of the child's capacity usually cannot be obtained from the parents; therefore mild incapacity was reckoned to be present if the child was able to walk to school or was able to play all but the more strenuous games; moderate limitation was present if the child avoided active games, and was unable to walk to school, and severe incapacity if the exercise tolerance was limited to walking across the room, and to 'parlour-games'. These criteria, while rough and ready, are realistic, and obviate the mistakes made by relying upon the parent's optimistic estimation of the exercise tolerance, and exclude the artifical reaction of a child in the ward, where his tolerance may be apparently impaired merely by flat uncooperation with the examiner.

The age-onset of dyspnoea is occasionally difficult to evaluate by a retrospective history. Often a mother is unaware that dyspnoea is in fact present until she is given a comparison with a normal child. In estimating this symptom in the present series, unless breathlessness was a spontaneous complaint, and the examiner observed its definite presence, the mother was given the opportunity to compare her child with a normal, both at rest and on exercise. Any doubtful cases were discarded. The table (3) then reveals that the age onset of exertional dyspnoea is rather variable; the larger percentage of the cases studied showed this symptom at birth.

Paroxysmal dyspnoea was noted in 12 of the 40 cases, and was associated with early death in two-thirds. The symptom improved with operation in 2 cases where it was present, and disappeared in one case before surgery was done. It is interesting to speculate on the reversal of this sinister symptom in this child. Possibly there was increase in the compensatory mechanisms; perusal of the blood-count showed no rise of haemoglobin and red cells concomitant with the disappearance of paroxysmal dyspnoea, so that hypertrophy of the bronchial arteries may have been the cause.

Squatting

This occurred in 44% of the patients who were old enough (i.e. more than 1 year) to show the symptom. The significance of this finding was emphasized by Taussig (1947) who considers it specific for conditions in which the lungs are rendered oligaemic, particularly in tetralogy of Fallot. It is found, as will be later shown, in such conditions as atrial septal defect with pulmonic stenosis, and also in tricuspid atresia. Mannheimer (1949) has noted its occurrence in Eisenmenger's complex.

The table (4) reveals that the age - onset of squatting follows closely the age at which walking commences, tho' in one case it was delayed until 11 years. The incidence of 44% of the cases at risk (25) is much lower than that given by Mannheimer (1949), who states

that 81.6% of his cases of tetralogy showed squatting. Similarly only 2 of Taussig's 500 cases of cyanotic congenital heart disease did not squat. This disparity in figures is difficult to explain, as the symptom was specifically asked for, and demonstrated to the parent, if any difficulty with nomenclature was suspected. It has been noted from personal observation that "squatting", especially at play, may be seen in normal children. This was confirmed by questioning mothers attending at a local well-baby clinic. It is of course a comfortable position, at least for the young. One should not of course dismiss it as 'normal' as did the mother of one grossly cyanotic youngster. Her attitude was that since here husband (a healthy farmer) adopted the position for his 'al fresco' meals, the child 'must have copied him'. Squatting was absent even in some cases where paroxysmal dyspnoea and praecordial pain - both symptoms of severe affection were present.

Praecordial pain (see table 5)

This is a notoriously difficult symptom to evaluate in young children, whose sense of localization is primitive. Thus the incidence here described - 4 of 17 cases thought to be old enough to complain of it, must be taken as approximate. Probably the incidence errs on the low side. The pain when present and accurately described, was located in the mid-sternal area, sometimes with radiation to the epigastric area. A true anginal distribution to the arms or chin was not seen in any of the 4 cases. In case 123, this symptom occurred 6-7 times daily, and, as with the others, was relieved by rest. It is observed tho' again this has probably little significance, that the symptom seemed more troublesome in the high temperatures and humidity of a Wisconsin summer. In one case, (of atrial septal defect with pulmonic stenosis) an electrocardiogram taken very soon after the onset of one of these attacks of pain showed no variation from that taken previously.

Attacks of unconsciousness (see table 6)

This occurred in 6 of the 40 cases, in one case (33), this was the first symptom, and was mistaken for epilepsy. In all cases where present, the attacks began in infancy. It was a terminal event in 1 case, and death occurred in 2 other cases presenting this symptom. The phenomenon has been well documented by Abbott (1928), and its sinister import illustrated by Mannheimer, (1949), who noted its presence in 80% of fatal cases of tetralogy.

General symptoms

(1) Frequent respiratory infections (see table 7)

This was a principal complaint in 17 of the 40 cases, all seen as infants. In 3 cases, this was almost continuous; and was found to be very difficult to treat. Generally it took the form of a preliminary coryza, followed by tracheo-bronchitis. The syndrome typically cleared rapidly on the exhibition of antibiotics, but would often occur again after a few days or weeks. A total of 3 months was spent in hospital by case 70 because of intractable respiratory affections. As in acquired types of heart disease, a respiratory infection might precipitate congestive cardiac failure. This occurred in cases 4 and 128. Similarly, cyanosis was noted for the first time following bronchitis in case 52, and an intermittent cyanosis became constant following bronchitis in case 85. However, concomitant closure of a functioning ductus arteriosus may have determined this event in the latter.

Much parental worry and expense is caused by the frequency of respiratory infection in these children, and efforts at prophylaxis (except against pertussis) are difficult and unsatisfactory.

Other symptoms

While less dramatic than cyanosis or dyspnoea, certain symptoms collectively reflecting 'failure to thrive' are common in tetralogy of Fallot, as in other congenital cardiac defects (vide infra).

Table 8 summarizes the relevant findings, but do not reflect the degree of maternal misery which ensues, nor the relative unimportance of cyanosis or dyspnoea compared to poor appetite in the minds of many mothers.

Poor appetite, together with difficulty in feeding, the latter often unassociated with prandial dyspnoea are the commoner findings; some of these babies, whose exercise tolerance is often only minimally reduced will take up to 1½ hours to absorb 3-4 ounces of formula. The paediatrician, who advises increased intake of fluids as a prophylaxis of venous thrombosis is liable to find that his advice is empty; review of the actual intake by the children of even the most devoted of mothers or skillful nurses shows disappointing averages in many cases. In conditions of high external temperature and humidity, it has occasionally been found preferable in hospital conditions to employ an indwelling polythene gastric tube. In one case the technique was demonstrated to an intelligent mother who practiced it successfully at home; in a few cases, and under hospital conditions, it was found ~~that~~ possible to assess the childs caloric intake. In the more severely affected children,- those with urgent dyspnoea on feeding, great nursing care and patience was necessary to achieve even a minimal intake. It is in such cases that the 'gastric-drip' technique is useful; this gives maximal caloric intake with a minimum of energy expenditure in a severely affected infant.

Irritability too is a common enough symptom, and one which causes much distress to the parents. The judicious use of chloral hydrate or phenobarbital is a useful adjuvant in the management of these patients.

Poor weight gain and refusal to grow are almost universal, initial complaints, and may occur before the onset of frank cyanosis or dyspnoea.

The signs

Cyanosis and dyspnoea have already been discussed, The subject of heart disease focusses attention on cardiac murmurs, and therefore

these will be considered first.

As a preliminary however, it is necessary to consider the peculiar difficulties of eliciting these physical signs. It has been noted that the referring letter frequently quotes the presence of a 'continuous' murmur. On examination, this is found to be systolic only. The 'diastolic' element is almost invariably breath-sounds heard in the filling period. When one considers the fact that the cardiac rate may be 120 and the respiratory rate 60, it is obvious just why this should occur. This illustrates only one facet of the difficulties of cardiac examination in early infancy. Also, the small size of the chest complicates the finding of the point of maximal audibility of a murmur. This may be partially overcome by the use of a small stethoscope bell; the position of a thrill, which is commonly well localized, is a most useful aid. The transmission of a murmur may be quite wide, again purely related to the short distances involved in the infant chest. The table (9) which follows should be interpreted with these facts in mind.

As far as possible, the child was quiet, preferably asleep at the time of auscultation. The praecordium was palpated for a thrill, and this was followed by auscultation at the usual areas; both axillae, and the back were examined to assess the areas to which transmission took place. Particular attention was paid to the quality of the 2nd sound in the pulmonary area, in an effort to assess the incidence of "weakening", absence, or reduplication of this sound. In older children, phonocardiograms were made in some patients; the problem of routine recording in the average infant was found to be well-nigh insuperable with the apparatus available (a Sanborn type): this was due principally to the lack of cooperation (crying) in the infant, even after mild sedation, so that the interference of breath-sounds caused much artefact in the tracing. Usually the murmur was recognizable, but little other detail was found. It was thought that this method

of investigation is of little value in the examination of infants with Tetralogy. Mannheimer (1949), however, suggested that where "weak" murmurs were present, that a phonocardiogram might reveal a tracing with a pathologically high frequency. However, as will be shown here and has been shown by others (Brown 1950, Taussig 1947), the bruit is very variable. Taussig (1947) points out that the murmur may only be heard when the patient leans forward. Potts (1952) similarly observes that the bruit may vary from "the merest scratch to a harsh rasping sound." The question of the absence of a murmur has intrigued many observers. Taussig (1947), feels that the absence of a murmur argues a high degree of pulmonic stenosis; Potts (1952) similarly feels that this reflects pulmonary atresia; Brown (1950) holds the same opinion, while adding that this may occur where a "large septal defect is unfavourable for the production of any murmur".

Table 9 summarizes the auscultatory findings; included also is a note of the incidence of thrills, which occurred in 22 cases (55%). In 4 cases (10%), there was no murmur audible at all. In 2 of these, autopsy showed complete pulmonary atresia, in another this was suspected, but no autopsy was done. In another, although post mortem was refused, the pulmonary artery was noted to be of fair size at operation, which does not suggest that atresia was present. These findings certainly favor the impression that an absent murmur equates well with pulmonary atresia, though the last instance quoted is definitely against this.

The majority of the cases had a systolic murmur, usually loud. Its audibility is assessed on the basis of the standard laid down by the American Heart Association. Wide transmission was usually present, generally to the left axilla and back. The point of maximal audibility was usually at the left sternal border at the level of the 2nd - 4th interspaces. As will be shown in a later chapter, this compares very closely with the findings in some cases of atrial and ventricular septal defect.

These findings are essentially those reported by Mannheimer (1949) and by Ash and Harshaw (1939); though the number of cases where a murmur was absent is rather higher than in the former study.

As the table shows a diastolic murmur was heard in only one case. This boy had an associated arterio-venous aneurysm of the right lung. This doubtless explained this sign.

The 2nd pulmonary sound at the pulmonary area was reduced in 7 cases; it was loud in one, the otherswere deemed to be normal. This suggests that undue importance has been attached to the quality of the pulmonary 2nd sound by some authors. Thus Taussig (1947) states that this sound isweak, tho' she qualifies the statement by saying that aortic valve closure may be heard better at the left than right of the sternum. It is difficult to see the point of this remark. Brown's comment that reduction of the second sound seldom occurs seems much more a propos of the actual findings. In no case of the present series was reduplication of the 2nd sound heard, in accordance with Bing's (1951) remark that reduplication implies the presence of two functioning vessels, assessment of the 2nd sound as 'aortic' or 'pulmonary' components as described by Leatham (1952) was found to be very difficult in these children, probably because of the large number of infants. Gallop rhythm was heard in one case only.

Growth and development

Growth was markedly impaired in most cases; the relevant data is given in table 10. These findings agree well with Taussig (1947), Potts (1952) and Mannheimer (1949), though somewhat at variance with the results recorded by Campbell and Reynolds (1949) who found that 97% of their tetralogies were of average normal height.

The milestones of development

These were assessed by reference to the temporal development data given by Ellis (1951). The points enquired for were those of motor development. Time of holding up head, rolling over, sitting

unaided, standing, walking and talking. Six of the 33 cases at risk (7 were too young for assessment), were thought to be retarded. Temporal variations occur of course, but in one case, a twin, the unaffected child was approximately 12 months in advance of his sibling. Naturally delay in development is a non-specific symptom, and in tetralogy, reflects merely the decreased exercise tolerance of the condition. Only one case was thought definitely to be mentally defective. In reviewing cases of tetralogy Mannheimer (1949) records 2 cases of mental defect. This is a slightly higher incidence than in this series but probably is without significance. Campbell and Reynolds (1949), noted that lateness in walking was common in their series, which included a large number of tetralogies. They felt that the mental condition was usually normal. It is probable that this series is too short to allow for any definite conclusion to be drawn in this regard. As a side observation, it may be noted that a large percentage of these children were difficult to deal with. Parental over-sympathy, and the inability to lead a sort of normal life led to many tantrums and difficulties. This symptom was usually much relieved if success followed operation.

Clubbing

This is a common sign in tetralogy of Fallot. Brown (1950) states that this is very rare in the first 2 years of life, and is never present at birth. With the last statement it is possible to agree. Taussig (1947), agrees that clubbing is seldom seen in infancy. Mannheimer in his series, which included conditions other than tetralogy found this sign in 64.4%, and noted its infrequency in infancy.

Table 11 breaks down the incidence of this sign, which was seen in 23 of 40 cases. Of course not all children were seen in the first year of life, and this is a deformity which mothers seldom note. However, clubbing was seen in 4 children who were less than 1 year old; it is suggested that this sign may not be so uncommon in infancy as heretofore supposed. The incidence in children under 1 year was 4 of 14 or 28%, and several of these cases died in early

unaided, standing, walking and talking. Six of the 33 cases at risk (7 were too young for assessment), were thought to be retarded. Temporal variations occur of course, but in one case, a twin, the unaffected child was approximately 12 months in advance of his sibling. Naturally delay in development is a non-specific symptom, and in tetralogy, reflects merely the decreased exercise tolerance of the condition. Only one case was thought definitely to be mentally defective. In reviewing cases of tetralogy Mannheimer (1949) records 2 cases of mental defect. This is a slightly higher incidence than in this series but probably is without significance. Campbell and Reynolds (1949), noted that lateness in walking was common in their series, which included a large number of tetralogies. They felt that the mental condition was usually normal. It is probable that this series is too short to allow for any definite conclusion to be drawn in this regard. As a side observation, it may be noted that a large percentage of these children were difficult to deal with. Parental over-sympathy, and the inability to lead a sort of normal life led to many tantrums and difficulties. This symptom was usually much relieved if success followed operation.

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life before this sign might reasonably be expected. The association with polycythemia was well marked, in accordance with the findings of Brown (1950), Taussig (1947), Mannheimer (1949), and other authorities.

Deformity of the chest (Table 12)

This sign was found in 40% of cases of morbus caerulens by Mannheimer and is said by Taussig (1947) to be due to great right ventricular enlargement at an early age, when the bones are soft and subject to deformity! Naish (1947) thought that Harrison's sulci were more common in children with congenital heart disease, rickets, or with a history of bronchitis or measles. The table shows the incidence and type of chest deformity encountered in this series. Sixteen of 40 cases showed some form of deformity. In one this was a 'trichterbrust', undoubtedly of congenital origin. In most cases there was bulging of both sides of the upper chest wall, with some protrusion of the sternum. Harrison's sulci occurred in a little over 25% of those with chest deformity, and was not associated with rickets.

Bulging of the left upper chest has been noted as early as $3\frac{1}{2}$ months of age in this series. By the age of 3 years marked bilateral bulging with deep Harrison's sulci has been noted (Case 43). In one case, initial unilateral left sided bulge observed at 4 months of age is in process of "ripening". Bilateral bulging, (left more than right) was noted by seven months and Harrison's sulci were becoming prominent by the age of 9 months. As will be shown later, these phenomena are rather more common in the 'shunt' syndrome; the incidence here however in the tetralogy compares well with that noted by Campbell and Reynolds (1949) - 136 of 332 cases.

Other signs

Epistaxis occurred in one case only, though Brown (1950), states that this symptom is not uncommon; dilated veins were frequently seen, most often on the head and fingers. This latter symptom was particularly searched for in view of the remark by Astley and Parsons (1952), that

this is a common feature in transposition of the great vessels. It was found in 3 cases; all of whom were severely polycythaemic. This is a non-specific finding, and as will be seen later, was found in cases of tricuspid atresia and septal defects with pulmonary stenosis.

Complications

In 2 cases (cases 4 and 128), congestive cardiac failure was noted. This occurred at the ages of 4 months and 2 weeks respectively. Usually the first indication of this trouble was an undue gain in weight. Early enlargement of the liver (Taussig 1947), was also a useful sign; bulging of the neck veins was found, though this seemed a less useful sign, as the frequent crying of these babies will distend the veins in any case. The lungs were free of basal crepitations, and compares with Taussig's (1947) statement that this sign argues a good circulation to the lungs. Peripheral oedema became obvious in both cases. Digitalis and mercurials relieved the condition in case 4 who is still alive one year after the first incident, but case 128 died unrelieved.

C.N.S. complications

The high incidence of complicating affections of the nervous system in congenital heart disease is well documented. Thus Peacock (1866), considered this the usual mode of death, and Brown (1950), and Taussig (1947), consider intra-cerebral accidents to be commonplace. The latter author considers that a high blood viscosity associated with polycythaemia is a leading factor, and stresses the importance of pressing increased fluid intake as a prophylaxis. Neurological phenomena, not related to surgery, were observed in 3 cases (71, 184, 187). In case 71, age 9 months, the condition of right hemiplegia, with stiffneck developed while in hospital when fluid intake was good. The haemoglobin level was 15.0 gms. which cannot be considered excessive. C.S.F. culture was negative. Death occurred, but permission for autopsy was refused. The suspected diagnosis was cerebral venous thrombous - aseptic? Case 184 developed hemiplegia

soon after a respiratory infection at age 8 months. Lumbar puncture produced normal fluid. Death occurred shortly afterwards. Autopsy revealed widespread cerebral venous thrombosis. Case 187: child was admitted with generalized convulsions; these passed off in 12 hours but the child was noted to be in a state of decerebrate rigidity. Peripheral gangrene appeared and death occurred. Autopsy showed a septic phlebo-thrombosis of the cerebral vessels, with areas of marked encephalomalacia.

Tuberculosis

Tuberculin tests were routine, but no reactors were found. This is in keeping with the results in the general child population of Wisconsin who are admitted to the children's ward here; likewise there were no clinical or radiological evidence of tuberculosis. This is in disagreement with Brown's (1950) finding that tuberculosis is not infrequent in children with this disease. The relatively young cases here considered, and the high mortality, probably load the series on the side of optimism as far as the incidence of tuberculosis is concerned.

Bacterial endocarditis

The frequency with which bacteraemia and endocarditis complicate congenital heart disease has been commented upon by Abbott (1951) and Ash and Harshaw (1939). Brown (1950) however comments that endocarditis is not a frequent complication of tetralogy as compared with other lesions. Certainly the diagnosis was occasionally entertained in some cases in this series, but blood-cultures were invarably negative; in case 187 a septicaemia existed, probably having its origin in a mural thrombosis of the right ventricle. This had caused septic infarcts of the lungs and kidneys, and gangrene of extremities; as noted above, septic thrombo-phlebitis of the cerebral veins also occurred. Notwithstanding, the deformed heart was apparently free of localized endocarditis (c.f. a case of Brinton and Campbell 1953).

In fine, no proven case of bacterial endocarditis either of the acute or subacute type was found. This reflects the statistics of all of the other cases of congenital heart disease here studied. Perhaps the routine use of antibiotics in the respiratory infections has been of some help in the prophylaxis of this dangerous complication.

Special investigations

I. The Electrocardiogram

Einthoven (1908) stated that abnormal QRS patterns were principally found in persons with congenital heart disease. Irvine-Jones (1926) in her review of cases with this affection noted right axis deviation in a large percentage. Mannheimer (1949), found this in only 53%, of cases of morbus caeruleus. Wood (1951) states that right axis deviation is usual in cases with pulmonary stenosis, and in common with Katz and Wachtel describes high peaked 'P' waves as being common in morbus caeruleus. Schnitker (1940) came essentially to the same conclusion. Most authors are not so careful as Mannheimer who, with reference to axis deviation, took care to include a control series, and showed a significantly greater angle of right axis deviation in a series of cases of cyanotic congenital heart disease. He points out that the 'right axis deviation' of normal newborns is greater than that of established cases of tetralogy; the range of variation in the normal E.C.G. is considerable, as is shown by Ziegler (1951) who states (p.56) that 'the position of the mean electrical axis of the QRS as determined by the extremity leads, either umpolar or bipolar, may be influenced by (1) the position of the heart in the thorax (2) the pattern of intraventricular conduction (3) the relative size of the two ventricles.' He feels that 'the relative important of these various factors varies according to a number of different circumstances in each individual case, and must be resolved by combining information from the extremity and precordial lead patterns, and perhaps data from a roentgenological survey as well!
In another section (p.75) devoted to the 'intrinsic ventricular deflections'

he notes that the wide range of variation in individual measurements and multiplicity of factors which may influence their measurements, limit their value as specific evidence of ventricular enlargement.

These turgid statements suggest then that (1) the range of normal is great (2) it is difficult in infants to be sure on E.C.G. evidence that ventricular hypertrophy is indeed present. The influence of the position of the heart within the thorax on the E.C.G. has been elucidated by Wilson and his associates and the rules for finding the portion delineated by him; the method of unipolar limb-lead electrocardiography is essential in the full examination of a case.

Apart from the problems of the infant (noted above), the problem of how to check on the presence of right ventricular hypertrophy is one of considerable difficulty. The basic patterns described in the standard texts are rooted in the findings in adults; the question of when these findings become applicable to children is of some interest.

Wood (1951) states that right axis deviation is normal in infants, and is common in young children, and that inspection of the limb leads may be of little value in assessment of this finding as far as right ventricular dominance is concerned. His criteria for this latter phenomenon are (1) a taller 'R' than usual in VI: delay in the intrinsic deflection, a deep 'S' wave in V5 and V6, secondary inversion of 'T' wave, and depression of the R-T segment in V1 - V3. Graybiel (1951) adds to these shift of the transitional zone to the right (in the praecordial leads). In addition he points out that the augmented unipolar limb leads will show in many instances a horizontal heart; Wood (1951), in this regard comments that clockwise rotation about the long axis (as reviewed from below) will also occur.

The table illustrates the principal findings in the electrocardiograms in this series. As is shown, and in accordance with the criteria of Woods (1951), Taussig (1947), and Brown (1950) many cases showed

peaking of the 'P' waves, especially in limb leads I and II. Right axis deviation was seen in most cases (except one); not all cases had praecordial leads recorded, but right ventricular dominance was seen in many of those where this was done. As discussed above the criteria are still in a state of flux, and these findings are presented without comment. Potts (1952) notes that right axis deviation is an invariable finding in tetralogy. So it is of course in infants and in many young children. Only two cases here showed no axis deviation, and one showed a peculiar pattern which has already been reported by Brown (1951) though he notes this finding in conditions other than tetralogy.

A prolonged P-R interval was seen in a few cases, but in none was this beyond the maximum reported in normals by Ziegler (1951); there was no case of other conduction defect in this series. This is in accordance with the findings of Paul, Myers, and Gordon (1951).

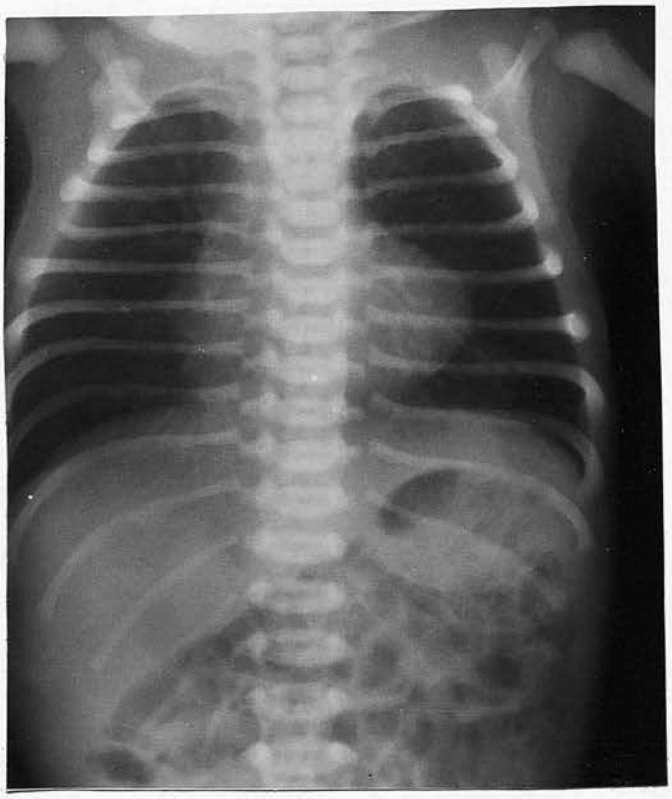
In summary, peaking of the 'P' waves in lead I and II is a usual though not invariable finding. Right axis deviation is usual, but may reflect the physiological condition in infants and some young children; where praecordial leads are taken, right ventricular strain patterns, as assessed by adult standards may be found. There is some evidence (Ziegler 1951), that these are not applicable to infants and young children; no cases of conduction defect were noted in this series. One case where the lesion was associated with complete situs inversus showed a normal E.C.G. upon reversal of the relevant limb leads.

II. The radiological findings

The classical radiological findings in tetralogy were described by Assman (1929), Harrison (1929), and Papp (1931) and consisted in a relatively normal heart size as seen in the A.P. view, together with a concavity in the area of the pulmonary arc. A right aortic arch was often also associated.

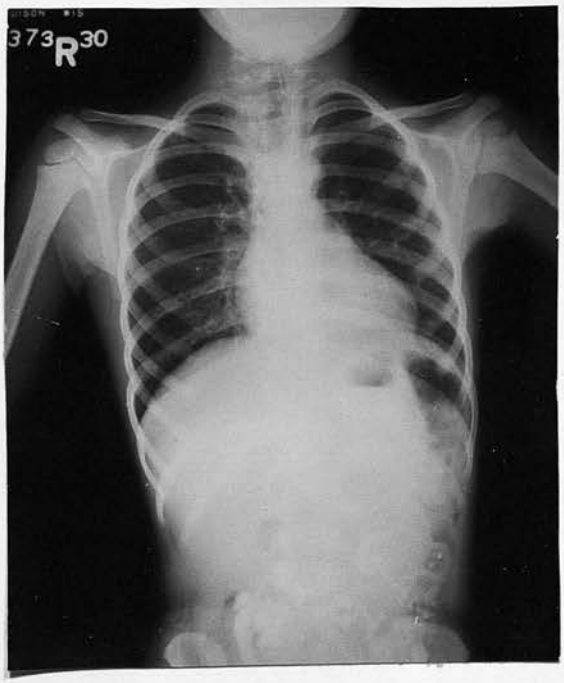
These findings have been amplified by Taussig (1947), who notes that in addition to the above findings, oblique fluoroscopy reveals

TETRALOGY OF FALLOT
PLATE 1 - CHILD AGED 2 MONTHS



This plate shows the classical 'coeur en Sabot' appearance.

PLATE 2 - CHILD AGED 7 YEARS



This film shows post-stenotic dilatation of the pulmonary artery.

right ventricular enlargement, and, in the right anterior oblique, absence of the normal fullness of the pulmonary conus. She also discusses the appearance due to a right aortic arch, and the importance of diminished vascularity of the lung fields. She states in addition, that the degree of right ventricular enlargement may be assessed in the L.A.O. view by showing the advance of this chamber towards the sternum in relation to the ascending aorta. In regard to left ventricular enlargement, the angle of clearance in the L.A.O. according to Wilson (1934) normally 50+ degrees; more than 55 degress being considered abnormal.

Eek (1949), takes issue with Taussig in regard to right ventricular enlargement in the L.A.O. and suggests that estimation of enlargement of this cardiac chamber in relation to the aortic line (a line drawn from the most prominent part of the arch aorta parallel with the sternum) is uncertain in specific cases, and was not a constant finding in his series of tetralogies. Similarly, in relation to the angle of clearnace of the left ventricle in the L.A.O. he notes that Wilson's data does not hold for Tetrads, since the left ventricle may be displaced posteriorly by the enlarging right ventricle, so that a greater angle of clearance results, which is unassociated with true left ventricular enlargement. He suggest that a convex "cap-shaped" appearance is seen in the L.A.O. when the left ventricle is displaced over the spinal shadow by right ventricular enlargement. The position of the interventricular groove is also commented upon as a useful guide to ventricular size. However, the number of times in which this was visualized in his series was low. The fact that a good gastric gas bubble aids in recognizing this valuable sign suggests that the judicious use of aerated waters may aid in making it more obvious in children. Absence of vascular markings in the aortic window suggests absence of a left pulmonary artery (Taussig 1947).

The weakness of the cardio-thoracic ratio in the A.P. view as a measure of cardiac size is emphasized by Eek, since this method fails to take depth into account. The horizontal position of the heart in tetralogy likewise does not enter into the calculation.

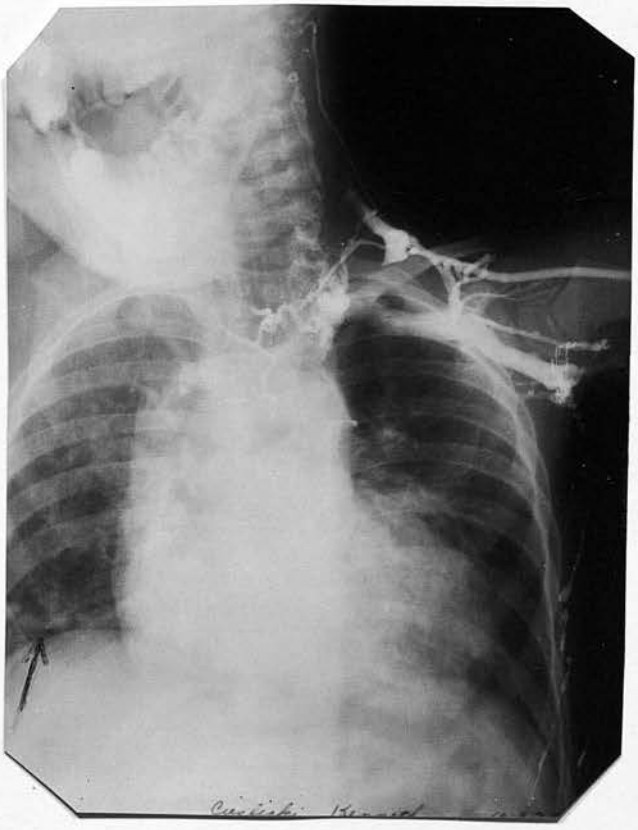
The results in this series are seen in table 14. All cases had routine chest films in the A.P., R.A.O., and L.A.O. positions and fluoroscopy was also carried out. This was done personally in only 40% of the series.

The findings essentially were those of others; abnormal concavity of the pulmonary arterial segment in the A.P. and R.A.O. views was seen in 23 cases. This was not found in 7 cases; 2 cases showed dilatation of this area. A right aortic arch was noted in 9 of 33 cases. Pulmonary vascularity was reduced in 24 cases, and was adjudged normal in 9 cases. Right ventricular enlargement was common, and occurred in 28 of 35 cases. A usual finding was filling in of the retrosternal space in the R.A.O. when the right ventricle was thought to be enlarged in the L.A.O. position. The phenomenon of apparent enlargement of the left ventricle in the L.A.O. was observed in 5 of 18 cases personally fluoroscoped. Eek's explanation of posterior displacement by an enlarged right ventricle was accepted as the cause of this appearance. The visualization on 2 occasions of the interventricular groove further supported this suggestion; in one case, where this phenomenon was present angiocardiography proved beyond doubt that the displacement was associated with a normal sized left ventricle (its size was calculated by subtracting the shadow of the opacified right ventricle from the total shadow).

Angiocardiography

This was performed in 20 of the 40 cases. The technique is fully discussed separately, and the risks noted. It is certain that angiocardiography finds a useful peace in the investigation of tetralogy. Thus it is possible roughly to assess the degree of over-riding of the aorta, and in some cases, whether the pulmonary

TETRALOGY OF FALLOT WITH ARTERIO-VENOUS ANEURYSM OF RIGHT LUNG



This angiocardiogram shows the dextroposed aorta. The arrow points to the site of the aneurysm. Note the increased vascularity of the lung on this side.

stenosis is of the valvular or infundibular type. The findings have been described by Dotter and Steinberg (1951) and, in the British literature, by Lowe (1953). The latter author critically reviews the diagnostic criteria; he notes the difficulty in visualizing the pulmonary stenosis and suggests that early opacification of the aorta, and fleeting opacification of the right heart (as described by Campbell and Hills 1950), are typical. In the differential diagnosis, he notes that early filling of the left atrium and more prolonged opacification of the right heart is common in pulmonary stenosis with intact ventricular septum, but with atrial septal defect. These were the common findings in the series under review.

In general the pulmonary artery and the aorta opacified simultaneously and in 5 cases the former was clearly enough seen accurately to localize the stenosis (cases 52, 65, 7, 47, 123). Post-stenotic dilatation was seen in cases 75, 123, 155. Distortion of the main branches of the P.A. was seen in case 7, and they were adjudged hypoplastic in case 65. An arterio-venous anerysum of the right lung vessels was visualized in case 148.

Cardiac Catheterization

The perfection of this method of investigation by Cournand et al. (1941), is of aid in the investigation of the tetralogy of Fallot. It is a time-consuming procedure, and is probably inferior to angiocardiography in the routine investigation of these cases. However much useful information may be obtained concerning the dynamics of the condition, and it is especially useful in the differentiation of cyanotic cases of atrial septal defect with pulmonary stenosis and a normal aortic root. This latter may be mistaken for tetralogy even with angiocardiography, and if a 'shunt' operation is performed, cardiac failure may ensure.

Cardiac catheterization will give information as to the type of pulmonary stenosis, whether valvular or infundibular. This is obtained by examination of the 'pull-back' from the pulmonary artery to the

right ventricle. A pressure record giving a sharp change from the low pulmonary artery pressure to the high ventricular pressure indicates a localized 'valvular' type. An area of intermediate pressure between the pulmonary arterial and right ventricular levels suggests an infundibular type. This information is of great value to the surgeon.

The Fick principle can be used to assess the systemic and pulmonary flow, and the degree and direction of intracardiac shunt calculated. Bing (1952) remarks that a knowledge of these factors may contra-indicate the formation of a shunt, as this is hazardous in the face of a low systemic output.

Generally the aorta may be readily entered, thus demonstrating its "riding" position. It is not quite so easy to enter the pulmonary artery, and several were incomplete because of this.

In general the results obtained by cardiac catheterization were essentially those already well established (Bing 1952); moderate right ventricular hypertension, and over-riding aorta, and pulmonary stenosis of various types were demonstrated. Probably the most useful point was in the demonstration of pulmonary stenosis with atrial septal defect in cases falsely labelled as tetralogies.

Summary

Forty cases of tetralogy of Fallot are presented. The clinical phenomena are reviewed in detail, as are the electrocardiographic and x-ray findings. An appendix gives some illustrative post-mortem findings.

Appendix - Autopsy Reports

Case 187. - There was gangrene of left foot, thumb and index finger. The heart showed a typical tetralogy with a valvular pulmonic stenosis (P. valve bicuspid). Attached to the V. septal defect, and hanging in the left ventricle was an ante-mortem thrombus. There was thrombosis of the branches of the pulmonary arteries resulting in infarction which in turn led to several lung abscesses. A thrombus occupied the take-off of the left subclavian artery.

The brain was soft, and the right cerebral hemisphere showed encephalomalacia with multiple venous and arterial thromboses, with small areas of meningitis; both kidneys showed multiple small infarcts; 3 small abscesses were present in the left kidney.

Case 184. - Examination limited to the heart. The right ventricle was thickened; the aorta over-rode a large ventricular septal defect, which gave essentially a common ventricle. There was a complete valvular pulmonary stenosis. The foramen ovale showed probe patency; the ductus arteriosus had a patent 3 mm. lumen; an umbilical hernia was present.

Case 177. - Heart showed a typical tetralogy with a valvular pulmonic stenosis. There ~~was~~ were septic thromboses of the right femoral artery; both renal and right iliac arteries with incomplete thrombosis of the bifurcation of the aorta. The left kidney was completely infarcted. There was a left sided cerebral encephalomalacia, and a basilar meningitis.

Case 172. - The examination was limited to the heart, and this showed all the features of a tetralogy. The type of pulmonary stenosis was not noted. The ductus arteriosus was patent.

Case 171. - The heart showed a right sided aortic arch which straddled a ventricular septal defect. The right ventricle was enlarged. The ductus arteriosus was thrombosed. A single coronary sinus orifice was

present. A small atrial septal defect was present. There was pulmonary atresia; a left lung abscess was present. The spleen was absent. The pancreas and large intestine were entirely intraperitoreal.

Case 157. - There were bilateral cataracts and pectus excavatum. The right sided aorta over-rode a large ventricular septal defect. The foramen ovale was anatomically patent. The right ventricle was enlarged. The ductus was closed. The bronchial arteries were greatly hypertrophied.

Case 116. - Examination limited to thorax. The lungs showed some atelectasis. There was a typical tetral ogy of Fallot with valvular pulmonic stenosis. The valve had been split surgically in 2 directions and the small leaflets so formed were movable.

Case 70. - There was hare-lip and cleft-palate. Heart - the right ventricle was enlarged; the aorta over-rode a ventricular septal defect. The foramen ovale was anatomically patent; the ductus arteriosus was patent. A subvalvular pulmonary stenosis was present. The left kidney and ureter were absent. A round mass presented in the left paravertebral region near Lumbar I and II; this was indentified microscopically as a neurofibroma. The trachea and larynx contained aspirated formula. Patchy atelectasis of both lungs was present, and microscopy showed early pneumonia. Microscopy of heart - occasional areas of sub-endocardial fibrosis were present.

Case 52. - Typical tetralogy of Fallot with a valvular (bicuspid) stenosis which had been cleanly split by a valvulotome. Patchy atelectasis of both lungs was present.

Case 11. - The aorta over-rode a ventricular septal defect 1.4 x 1 cm. A large patent ductus arteriosus was present. Infundibular and valvular pulmonary stenosis was present. A small (5 mm.) atrial septal defect was present. On opening the pulmonary arteries, organized thrombi were present in the right and left branches and main trunk. Microscopically there was organization and some calcification present.

Comment

The pathology of the tetralogy of Fallot is well known and though some

writers (Brinton and Campbell 1953) separate the cases associated with pulmonary atresia, this has not been done in this series because of the small number present. It is obvious that the single most important lesion is the pulmonary stenosis, and its site is important from the standpoint of surgical treatment. Recent series (Brinton and Campbell 1953) suggest that infundibular stenosis is present in one half of cases; valvular stenosis in one third, and the remainder present as infundibular and valvular stenosis. Allanby (1950) found only 4 of 44 cases to have pure valvular stenosis. It seems obvious that the position is still fluid. Brock (1950) has described a method of ascentaining the site of stenosis at operation, and with more valvular surgery being done, more data will accumulate. The value of angiocardiography in delineating the stenotic area has already been commented upon. Personal experience has shown that the fixation process will contract the infundibulum so as to give a false impression of the degree of stenosis present. Brinton and Campbell comment on this also, though stating that angiocardiography may show this in life when autopsy shows valvular stenosis only. It has been suggested (Kirklin et al. 1953) that the muscular hypertrophy of the right ventricle may encroach upon the outflow tract, to cause an infundibular narrowing which is not truly congenital. A preoperative method of assessing the site of the valvular stenosis is to carry out "pull-back" pressure recordings at the time of cardiac catheterization. A valvular stenosis will show a change in one beat from the low pulmonary arterial pressure to the high pressure of the right ventricle. An infundibular stenosis on the other hand will show an area of intermediate pressure between the pulmonary arterial and right ventricular tracings. Unfortunately, however, the success rate in entering a stenotic pulmonary artery is not high, and in addition the catheter may completely occlude the orifice with dangerous results. If the surgeon is willing to accept Brock's criteria for the site of stenosis, and to undertake a suitable surgical

approach, it would seem that preoperative cardiac catheterization is unnecessary.

The difficulty of assessing the degree of over-riding of the aorta is great; Brinton and Campbell (1953) estimate this by the ease with which the aortic valve was seen from the right and left ventricle respectively, checked by observation of the free edge of the ventricular septum seen from the aorta; this estimate is expressed as a fraction, and must be carried out on the unfixed heart. As no similar estimations by the same method exist, as in this series, this is an important point worthy of further attention.

A patent foramen ovale, a small atrial septal defect was found in 5 of the 10 autopsied cases, but the numbers included a large proportion of infants unduly loading the series, still the proportion is close to that quoted by Brinton and Campbell.

A large number of associated congenital defects both vascular and otherwise is shown in the table. The associated neurofibroma described in case 70 appears to be unique, no reference to a similar case has been found in the literature. The severe damage due to arterial and venous thromboses is well illustrated in cases 11, 177, and 187. The first is most interesting but not unexpected (see Rich 1948) in so far as marked thromboses, with subsequent organization was present apparently for some time before death. In this case there was a lengthy history of precedent diarrhoea, refusal to feed, and dehydration. This may have precipitated the condition, though the localization to the lungs remains unexplained, Rich considers this due to stasis in the pulmonary circuit. Case 187 had multiple embolic phenomena associated with a large ventricular artemortem thrombus. This is very similar to that of case 21 of Brinton and Campbell (1953) series, and in both, associated bacterial endocarditis was assumed to be present. The presence of aspirated feed in case 70 illustrates the great need for caution in the feeding of these debilitated infants. The presence of a functional or even large (case 11) ductus arteriosus does not always prove sufficiently effective.

In summary, the post mortem findings of 10 cases of tetralogy of Fallot are presented, with some observations on the pathology present. The high percentage of associated defects in the autopsied group compares well with those clinically obvious, and in congenital heart disease of all types.

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Section 3

TRICUSPID ATRESIA

Tricuspid atresia is said to be a rare condition (Brown 1950; Edwards and Burchell 1949). Collections of cases are however given by Abrams and Alway (1951). More recently (1953) Astley, Oldham and Parsons have described fifteen cases, and Taussig and Bauersfeld (1953) state that 62 cases were present in their review of one thousand cases of cyanotic congenital heart disease treated surgically. The earliest collection of value is that of Abbott (1928).

Variation in septal development has been the accepted cause of the condition (Brown 1950; Taussig 1947), but Sommers and Johnson (1951) in reviewing cases of 'pure' tricuspid atresia felt that the lesion might be satisfactorily explained on a mechanical basis.

The association with other cardiac anomalies has been remarked by the authors quoted above, except Sommers and Johnson (1951). Transposition of the great vessels appears to be common, and in some cases is beneficial, as in that reported by Hedinger (1915).

Edwards and Burchell (1949) discuss the variants on the pathology of the condition, and describe a most useful subdivision. They note that common to all cases are tricuspid atresia, patency of the atrial septum, and a large mitral orifice leading to a (massive) ventricle. The septal defect is described as being essentially a patent foramen ovale, though occasional cases are described in which the septum is greatly deficient, with a resultant common atrium. Both atria (if separate) are enlarged, and have thickened walls.

The subdivisions are primarily into those associated with transposition of the great vessels, and those with a normal vascular arrangement. The latter is associated with pulmonary atresia or stenosis. These are type II, and type I respectively, and the former is said to be most common, and in general to carry the worse prognosis.

From a physiological point of view these hearts are essentially

biloculate, since a common atrium is combined with a minute functionless right ventricle which is often buried in the wall of the major chamber. If pulmonary stenosis or atresia is present, a patent ductus arteriosus is essential to the preservation of the circulation until compensatory bronchial arterial anastomoses arise.

The clinical features have been admirably presented by Taussig (1947). Each subdivision as outlined above being considered under the generic term of underdeveloped right ventricle. Cyanosis is an early and constant symptom and is usually intense. Dyspnoea is usual, as is cardiac enlargement. Murmurs are inconstant, though the 'purity' of the second sound is remarked upon. Presystolic pulsation in a normal-sized liver is considered to be very suggestive of tricuspid atresia with a relatively well-formed atrial septum. Most other authors agree with these clinical features. The electrocardiographic and radiological findings will be treated later. Eleven cases are presented in this section; table 1 shows the age-sex distribution. Nine cases were seen at age 12 months or less, and five of these presented in the first month. The majority of the cases were female, as compared with an equal sex incidence in the series of Astley et al. No other information as to the sex incidence appears to be available.

The cases were routinely investigated (see table 2) by clinical examination, x-ray, and electrocardiography. Angiocardiography was carried out in four cases, and cardiac catheterization once. A Pott's operation was done in ? three (Table 2) four cases. Necropsy was carried out in four cases also. Table 2 summarizes the methods used, and illustrates the poor prognosis in this condition. Only 3 cases survive, 2 being 5 or more years old, one other at the moment of writing has attained one year. This latter is the only one in whom surgery has been of benefit. The cause of death, and Necropsy findings will be considered in greater detail later.

The principal complaints are listed in table 4, and consist, without

TABLE 3. PRINCIPAL COMPLAINTS

Case No.	
212	Cyanosis since birth, retarded growth
210	Cyanosis, cleft-palate
168	Cyanosis since birth
174	Cyanosis since age 1 month
177	Dyspnoea, cyanosis
40	Cyanosis since birth
39	Dyspnoea and cyanosis since birth
34	Dyspnoea and cyanosis since birth
15	Cyanosis on crying since birth
144	Cyanosis since birth
230	Cyanosis, swelling of feet

exception of cyanosis and dyspnoea. Table 5 lists all the symptoms, which are seen to be severe. Many cases have paraxysmal dyspnoea, all have poor appetite and retarded growth, though only two had frequent respiratory infections - a low incidence as compared with the tetralogy of Fallot or intra-cardiac shunt. A surprisingly high percentage (60%) had symptoms of central nervous system disturbance, usually convulsions or extreme muscular flaccidity, reflecting, the high incidence of cerebro-vascular accident in this series.

The signs, some of which of course are common to the symptomatology are shown in table 5. Cyanosis is commonly present at rest, and is of general distribution. Clubbing occurs as early as six months and is marked by eighteen months. Chest deformity, presenting as bulging of the left upper chest, with Harrisons' sulci is related to the survival age of the patient, so that it is rare in this series. Paroxysmal dyspnoea and syncope run in parallel, and were seen in a minority of the cases.

The murmur is nondescript but usually systolic in time. It is maximal over the mid left sternal border, and of variable transmission. A diastolic murmur and thrill only was found in case 212; this is of some interest, since diastolic murmurs are rare in cyanotic congenital heart disease. It may be due to a patent ductus arteriosus, or possibly to enlarged bronchial arteries. The latter diagnosis was favored in so far as the systolic element so common in ductus arteriosus was absent, and there was some radiological evidence of increased bronchial vasculative (Campbell and Gardner 1950).

The second pulmonary sound is said by Taussig (1947) to be of remarkable purity in non-functioning right ventricle. In this series, while the second sound was always audible, and single, it was not found to differ clinically from that found in many cases of the tetralogy of Fallot. Clinical cardiac enlargement was usually present.

Fullness of the neck-veins, as described by Astley and Parsons

was commonly seen, but was always of course associated with moderate dyspnoea at rest, which tends to invalidate this as a useful diagnostic point. Similarly, prominence of the veins of the fingers and head occurred frequently. The same authors (1952) in a separate paper have described this in transposition of the great vessels, though it is in fact, as already shown, common enough in tetralogy of Fallot, as well as the cases at present under review. Curiously enough squatting did not occur, tho' one child was most comfortable in the knee-elbow position.

Four cases (210, 168, 34, 15), had associated defects severe enough to remark attention. Two had identical cases of Klippel-Feil syndrome with suboccipital meningocoele. One had a severe cleft-palate and hare-lip, and another a large naevus of the right hand.

Congestive cardiac failure occurred in two patients and was a presenting feature in one (case 230). Apart from these, enlargment of the liver was not a feature. Most cases showed a polycythemia, though in two cases (34, 210), a progressive anaemia, was observed, the haemoglobin falling from 15.5 gms. to 7.1 gms. between the ages of one and six months in case 210.

The Wasserman and Tuberculin reactions were uniformly negative.

X-rays findings

The radiology of the condition has been well described by Taussig (1947) in her chapter on 'non-functioning' right ventricle. She emphasizes the lack of fullness, or concavity of the pulmonary arc, as seen in the antero-posterior view. In the left oblique, the diminution in size of the right ventricle with increase of the left ventricle is usually obvious. The vascular shadow is narrow, in the antero-posterior position, and remains so on rotation into the oblique position. The lung fields are commonly oligaemic.

Astley, Oldham and Parsons (1953) give a clear idea of the findings to be expected; these do not differ markedly from the description given

by Taussig above, but are subdivided into those cases with oligaemic lung-fields, and those showing normal or increased vascularity. They point out that this is, from the point of view of treatment, is the most important feature. In the differential diagnosis of tricuspid atresia from tetralogy, the 'square' shape of the heart in the former condition is emphasized.

The pertinent radiological findings in the present eleven cases are shown in table 7. 6

The heart size was normal in 2 cases, where viewed in the antero-posterior position (cases 210, 144). The former was aged two weeks only, and therefore this might be expected. In the latter, hypertrophy by the age of 8 months would be usual. Both cases were confirmed by autopsy. In the same two cases there was no evidence of chamber enlargement in the oblique positions. All the others had findings suggestive of enlargement of the left ventricle. There was no evidence of other chamber enlargement in most cases.

The pulmonary arc was abnormally concave in six of eleven cases. It was normal in appearance in the others, which is said by Astley et al (1953) generally to occur in those with normal or plethoric lung-fields. In this series, this association was noted twice, in once case (35), transposition diagnosed by angiocardiography was present. In the other (case 39) the full anatomical diagnosis is incomplete. The pulmonary arc in case 144 was thought to be at the lower limits of normal, autopsy revealed tricuspid atresia, pulmonary atresia without transposition but with a recently thrombosed ductus arteriosus. This latter lesion may help to explain the anomalous x-ray findings.

Pulmonary obligaemia was almost always present. It was the sole radiological abnormality in case 144, in whom the diagnosis was proven at autopsy.

An unusual appearance was that of a circular shadow in the right upper mediastinum in case 168. This mimicked closely the appearance

of a persistent left superior vena cava draining the pulmonary veins, as described by Gardner and Oram (1953). This case will be discussed separately.

In general, pulmonary obligaemia, concave pulmonary arterial segment, and enlarged left ventricle were the usual appearances. Enlargement of the superior vena-cava, as described by Taussig (1947), was not seen; minimal left atrial enlargement was seen twice.

The angiocardiogram

Four cases were subjected to this method of examination (211, 168, 35, 144).

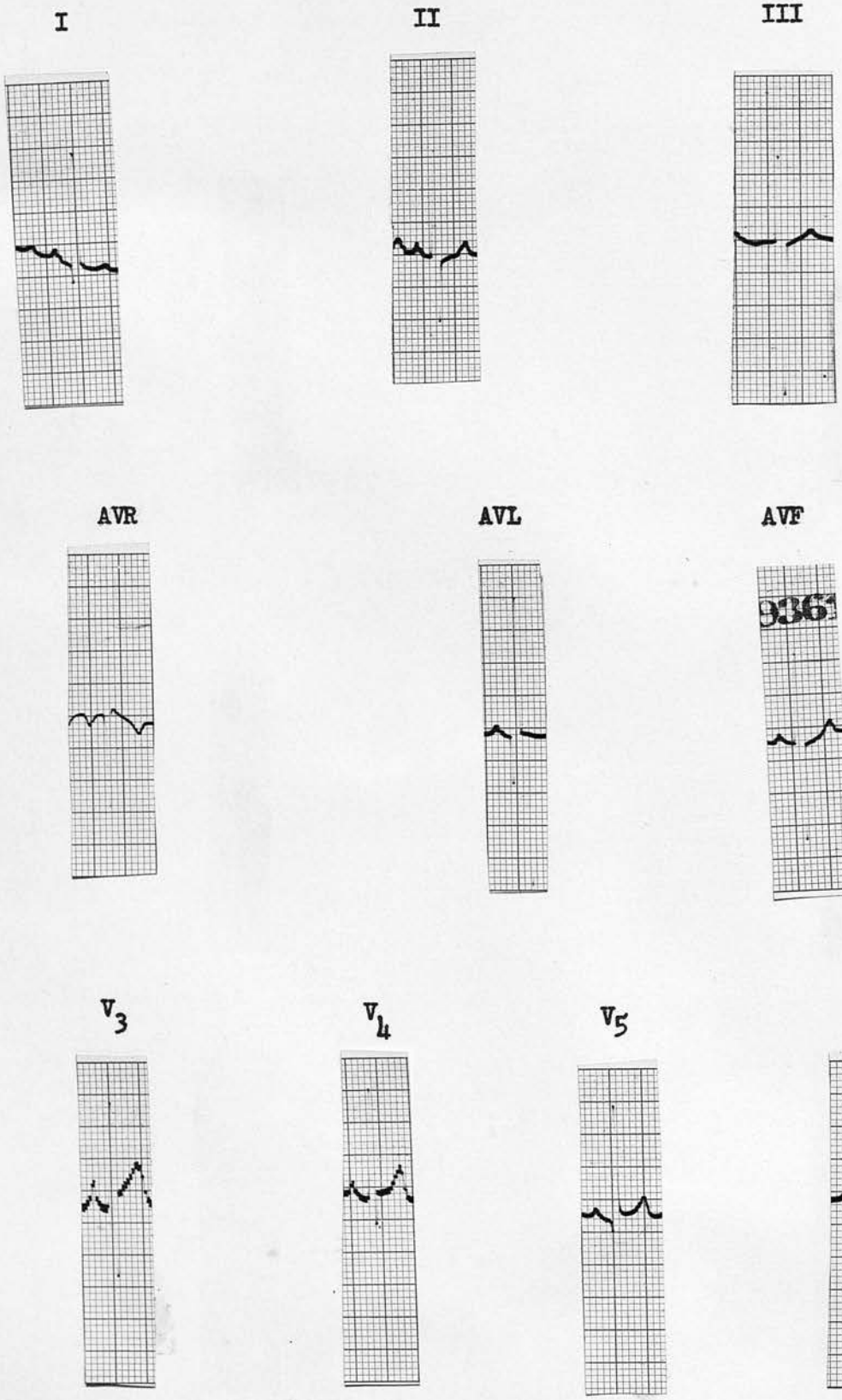
The typical findings are summarized by Dotter and Steinberg (1951), and Campbell and Hills (1950). The medium is seen to pass rapidly from the right atrium, which may be enlarged, directly into the left atrium and ventricle. The right ventricle, if outlined, is hypoplastic, and the pulmonary artery may opacify after the aorta. Astley, Oldham and Parsons (1953) note the usefullness of the manoeuvre in demonstrating transposition of the great vessels. The typical angiocardiogram as above described was seen in cases 211, 144, and 168, though in the last, recirculation of the medium though anomalous pulmonary veins draining into the left sided superior vena cava gave a bizarre appearance in the later films. In case 35, the medium passed from the right to left atrium, and the pulmonary artery was outlined earlier and more clearly than the aorta, though the exact take-off of the latter could not be defined. This was interpreted as representing a transposition of the great vessels.

Certain of the radiological features found are illustrated in the appendix.

The electrocardiogram

Tricuspid atresia is one of the few forms of congenital heart disease in which this method of investigation is said to have a relatively high degree of specificity. Most authors (Taussig 1947, Sommers and Johnson 1951), agree that left axis deviation is almost

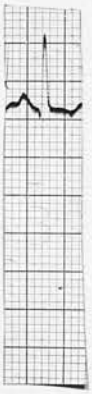
TRICUSPID ATRESIA WITH TRANSPOSITION (AGE 10 MONTHS)



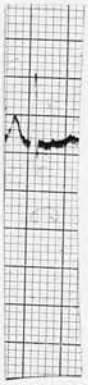
Note slight left axis deviation, semi-horizontal position and clockwise rotation. The 'P' waves are peaked.

TRICUSPID ATRESIA

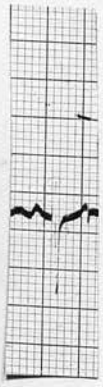
Case 15



I

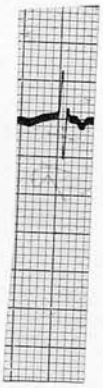


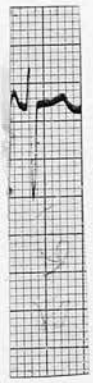
II

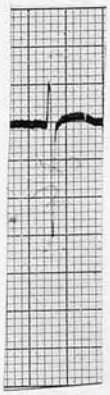


III

Case 39







Note left axis deviation.

invariable. Large voltage 'P' waves, usually in lead 2, are described by Geraci, Dry and Burchell, and occurred in the case of Kroop (1951). The latter notes the absence of left axis deviation in one of his cases, and this has been remarked by Brown (1936).

Table 8 summarizes the findings in the present series. The 'P' waves were high and peaked in six of the ten cases in whom electrocardiograms were obtained. Left axis deviation occurred in all but three cases of these last. Two were proven by angiocardiography (cases 212, 35), and the former at operation also. This child had a pattern consistent with right heart strain, tho' the angiocardiogram confirmed the minuteness of this chamber.

Case 177 showed right axis deviation, though tricuspid atresia was confirmed at post-mortem. Several of the electrocardiograms are reproduced in the appendix.

Complications

Table 2 gives these in detail and they were usually the cause of death. Congestive cardiac failure occurred twice, though in case 34, it was temporarily relieved by digitalis, and diuretics. Paroxysmal dyspnoea caused demise three times, once it was combined with bronchopneumonia, which though not clinically apparent, was obvious at autopsy. A cerebro-vascular accident was the cause of death in three. One (Case 177) being additionally complicated by an intussusception of the ileum which was not suspected during life.

The complications referrable to the central nervous system were manifested by convulsions (case 177, 34, 144), hemiplegia (case 34) and quadriplegia (case 144). All of these cases except 177 appeared to be well-hydrated. In addition another child (case 40) died with convulsions and irregular respiration, but involvement of the nervous system was only suspected, since autopsy was not carried out. The obvious neurological phenomena in the other cases seemed to prove the diagnosis, and in case 144, widespread cerebral venous thrombosis was found at autopsy.

This appears to be a high incidence of neurological complication compared to 4 of the 37 cases collected by Sommers and Johnson (1951). Apart from intussusception, the other causes of death listed are well recognized. No case of bacterial endocarditis was recognized, though blood cultures were made in all cases showing fever.

Post mortem examination was made in cases 210, 177, 144, and 230 and the results are recorded in the appendix; they are quite representative of the lesions which may be expected. (Edwards and Burchell 1949). Cases 210, and 144 correspond to types IB and IA respectively of these authors. Case 230 represents that described under type IIB. The additional complication of an aortic coarctation makes this case a rarity. Kroop (1951) however describes a almost similar case and comments that it (coarctation) may be found in cases of tricuspid atresia where transposition of the great vessels occurs with an adequate pulmonary circulation.

Treatment

General treatment will include the provision of an adequate fluid and caloric intake. This is no easy problem in these infants. Paroxysmal dyspnoea may be helped by placing the child in the knee-elbow position, and by the administration of Morphine (Taussig 1947). One of the cases recorded here, who had congestive cardiac failure responded for a time to digitalis and mercurials.

More specific surgical treatment may be used. This may be the Blalock-Taussig or Pott's procedure. Consideration of this is indicated in all cases of tricuspid atresia, where pulmonary oligaemia is present. The presence of transposition of the great vessels is not material in this circumstance.

Several authors (Gasul 1950, Taussig and Bauersfeld 1953), have commented on cases so treated. The mortality is greater, and the degree of recovery much less than in cases such as tetralogy of Fallot. Of the three cases treated surgically in this series only one is now alive.

One died unrelieved some months after surgery and another (case 144) had symptoms suggestive of cerebral thrombosis before operation and this was considered at autopsy to be the cause of death.

Not all cases will be suitable for surgery, because pulmonary atresia prevents a suitable anastomosis. This was the position in case 144, where the lower parts of the pulmonary artery was essentially atretic. Angiocardiography will be useful in some cases to demonstrate the presence or absence of pulmonary arteries.

Case 168 is one of great clinical and pathological interest, and will be discussed more full. She was cyanotic and dyspnoeic from birth, and displayed marked clubbing and retardation of growth. A loud systolic murmur and thrill was present in the praecordium, with the addition of a short diastolic murmur below the left clavicle: she had a full fledged Klippel-Feil syndrome. Polycythemia was marked.

Fluoroscopy showed the pulmonary vascularity to be at the lower limits of normal, and there was cardiac enlargement. A prominent convex shadow which was not pulsatile was seen in the upper right mediastinum. The E.C.G. showed left axis deviation. Angiocardiography showed a large atrial septal defect, without evidence of a right ventricle. A clinical diagnosis of tricuspid atresia was entertained, and it was thought that the mediastinal shadow resembled that reported by Gardner and Oram (1953) in describing anomalous pulmonary venous drainage into the great veins.

Cardiac catheterization was carried out, and the blood samples withdrawn from the superior vena-cava was many volumes above that in the right axillary vein. This proved physiologically that anomalous pulmonary venous drainage did exist. An atrial septal defect was demonstrated and the catheter passed into a ventricle and thence into the aorta. The pulmonary artery was never entered, in spite of repeated attempts; the oxygen content of what geographically was the left atrium was very close to that of the ventricle and aorta,

and therefore this ventricle was identified as the left chamber; the pressures here and in the aorta were comparable.

The final diagnosis then, arrived at by a variety of methods was: tricuspid atresia; atrial septal defect, diminutive right ventricle, and anomalous pulmonary veins draining into the superior vena cava.

It appears that anomalous pulmonary venous return is a condition of relative rarity (Brody 1942). The diagnosis has been made more frequently since the introduction of cardiac catheterization (Swan et al 1953). The paper by Brody contains details of the associated with anomalous pulmonary venous return.

It was of course impossible accurately to gauge the amount of circulatory deficiency due to this anomaly. Since the child was fairly active and able to attend school, no surgical treatment was carried out.

Summary

Eleven cases of tricuspid atresia are presented. The clinical, radiological and electrocardiographic features are described; it is shown that left axis deviation need not be present. An unusual associated defect - anomalous pulmonary venous drainage occurred in one case. The post-mortem findings are given in four cases.

Appendix

Autopsy Reports:

Case 210

The systemic veins drained normally into the right atrium. The site of the tricuspid valve was a small dimple in the endocardium. There was an atrial septal defect (foramen secundum) of 1 cm. in diameter. The left atrium received the pulmonary veins and opened by a normal mitral valve into a left ventricle of thickness 0.9 cm. The aorta rose in a normal fashion and was guarded by a bicuspid valve. It broke up into normal branches.

The left ventricle communicated with the right ventricle by a 1 cm. defect. The right chamber was of about 8 cc. capacity only. The pulmonary valve was bicuspid and stenosed. A ductus arteriosus was pin-point patent. The lungs showed broncho-pneumonia.

Case 177

The systemic venous return was normal. The right atrium was dilated and showed no tricuspid valve; it communicated with the left atrium by a foramen secundum of 1 cm. diameter. The pulmonary venous return and mitral valve were normal. The left ventricle (1 cm. in thickness) communicated with a tiny right ventricle by a septal defect. The pulmonary artery was normally distributed as was the aorta. The valves on both great vessels were normal. An intussusception of the terminal ileum was present.

Case 144

Autopsy showed tricuspid atresia. The auricles communicated by a septal defect of 0.8 cm. diameter. The right ventricle was tiny and buried in the wall of the left, communicating with it by a septal defect. The pulmonary artery was essentially atretic. Hydrocephalus and widespread cerebral venous thromboses were also found.

Case 230

The pulmonary veins returned to an atrium identified as the left; this communicated with a large ventricle by way of a normal valve.

The ventricle gave off the pulmonary artery which was normally distributed. The right atrium was somewhat enlarged and received the systemic veins normally. No trace of a tricuspid valve was found. It communicated with the left atrium. The right ventricle which was embedded in the ventricle already described gave off the aorta (which gave off the coronary circulation). The aorta was constricted as far as the entry of a patent ductus arteriosus.

Summary

Tricuspid atresia, transposition of the great vessels with "infantile" aortic coarctation. The condition is illustrated by the diagram.

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Section 4

TRANSPOSITION OF THE GREAT VESSELS

Transposition of the great vessels is a lesion of limited clinical importance, but of great pathological and embryological interest.

Many of the case-reports of historical note were concerned with a 'riding' or transposed aorta usually associated with pulmonary stenosis (Brown 1950).

Rokitanksy in 1875, considered that every case of transposition was primarily a maldevelopment of the bulbar septum; a shift to the left resulted in the aorta straddling the septum or actually rising from the opposite ventricle; at the same time this shift produced narrowing of the pulmonary artery.

Sir Arthur Keith (1909) considered that abnormal absorption of the bulbus resulted in transposition, the normal process being exactly reversed to produce this lesion. Spitzer was at pains to demonstrate that the normal process of mammalian cardiac formation was an increasing complexity of septation (as compared to lower species) at the behest of the need for more efficient pulmonary function. This septation process is dependent upon torsion of the developing organ so that chambers originally 'in series' become 'in parallel' while the separate pulmonary and systemic circulations lie eventually in series. The author's apologia in respect to normal development is a blend of phylogenetic and autogenetic argument. The latter represented by the increasing circulatory volume and altered and increased haemodynamics resulting from the development of an efficient pulmonary circulation. The former lie in the close analogy and Darwinian progression of the degree of torsion observable as one ascends the biological scale.

This becomes relevant to transposition when it is seen that the term is strictly a misnomer, as the 'transposed' aorta (in so called complete transposition) is really a reopening of the primitive right aortic ostium found in reptiles, with a suppression of the same structure

on the left. This is combined with the formation of a 'false' septum which will more or less completely separate the circulations; the whole being a result of incomplete torsion of the primitive heart. The theory may be extended to explain the anatomical findings in conditions such as over-riding aorta, and other varieties of transposition where the aorta rises from the right ventricle in common with the pulmonary artery.

It is interesting to note that this atavistic explanation of a congenital anomaly was suggested by Meckel and by Peacock, (1866) though without the detail of Spitzer.

Keith's (1909) opinion that transposition is an abnormality of bulbar absorption has already been mentioned. Lev and Saphir (1951), in their summary and analysis of Spitzer's monograph go far to support this argument. They adduce additional evidence from Pernkopf and Wittinger (1935) for the correct origin of the great vessels, and support this comparative anatomical study by one of their own (1945) upon cases of transposition. Spitzer's general theory of an ontogenetic complication of a phylogenetic variation is confirmed, but the latter results in abnormal absorption of the bulbus, so that the cause is not as Spitzer averred, a more primitive failure of torsion.

Occurrence

It has been stated (Keith 1948), that transposition of the great vessels has an incidence of 10% of all cases of congenital heart disease. Astley and Parsons (1952) state that is second only to the tetralogy of Fallot as a cause of persistent cyanosis.

In this series, thirteen cases were found where the diagnosis was confirmed at post-mortem or by angiocardiography. Two cases were further investigated by cardiac catheterization. There were five males and eight females, and the greater number were seen early in life.

The majority of cases were thought to have so called "complete" transposition, but two were shown to be suffering from the Taussig-Bing syndrome (proven at autopsy in case 97, suggested by angiocardiography

in case 128). These latter are being more fully reported elsewhere.

The symptomatology is shortly described in table 1; the details from which the table was constructed is given in the appendix.

In common with others, (Taussig 1947, Astley and Parsons 1952), cyanosis was invariable. In almost all cases it had onset at birth, though in case 128 (a Taussig heart), cyanosis did not appear until one year of age. Taussig has noted the importance of 'differential' cyanosis in the diagnosis of transposition. In only one case in this series was this sign unequivocally present. Astley and Parsons noted its occurrence in a roughly similar proportion.

Dyspnoea at rest was usual, and often of severe degree. The paroxysmal variety was not encountered, nor was syncope a feature in the history. In common with other varieties of inborn heart disease, frequent upper respiratory infections, poor feeding and small gain in weight were the rule.

Complications were frequent presenting phenomena, cerebral symptoms occurred twice, and congestive cardiac failure four times. The principal signs are tabulated (table 2). Enlargement of the heart was invariable, being present as early as the 5th day of life in case 182. The heart by x-ray had almost doubled in size by 10 days of age in this patient. This finding is well illustrated by Keith et al. (1953).

A systolic murmur was heard in all except one case. It was usually best heard over the left praecordium near the left sternal border and was transmitted to the left axilla. Occasionally it was loud enough to be heard in both axillae and in the back. In six instances the murmur had a corresponding thrill. The second pulmonary sound was readily heard and was single. Triple rhythm was heard once (case 26).

The incidence of murmurs in this series is higher than generally found. No murmur was present in 50% of Astley and Parsons' cases. Taussig states that the absence of a murmur is common, and considers that an associated ventricular septal defect is less likely in its

absence. Keith (1953) reports murmurs in only 2/3 of his patients. Of the children showing no ventricular septal defect, at autopsy, a murmur was heard in two of the three cases.

Bulging of the left upper chest, with Harrison's sulci were found in those children who survived more than eight months, though it was observed once in moderate form at the age of 4½ months. Clubbing had a similar incidence, occurring only in those who survived infancy. Praecordial pain occurred once.

Marked impairment of growth was present in the children who survived, the lag behind normals becoming more obvious with advancing age. Retardation of mental development was not remarkable except in the Mongols. Delay in walking was attributable to the low exercise tolerance.

Dilatation of the veins of the fingers and head is noted by Astley and Parsons (1953) as a useful sign in this condition. This certainly occurs in transposition, but has been observed also in cases of tetralogy of Fallot, atrial septal defect with pulmonary stenosis, and tricuspid atresia. It is a sign which is without specificity for transposition.

Radiology

Fluoroscopy is the most useful method of making a diagnosis of transposition. Taussig (1947) has presented the findings. Enlargement of the heart to right and left is common, with concavity of the upper left zone. The right auricle is enlarged, as are both ventricles, and the aorta is displaced forward when seen in the left anterior oblique position. The root shadow is narrow in the anterior position, but widens on rotation into the left oblique. The lung fields are generally hypervascular.

Astley and Parsons have somewhat modified this description, though finding the narrow vascular pedicle and concave left middle segment in a fair number of their patients. They noted that the presence of

a "long flat bulge" in the left middle segment (as seen in the A.P. view) suggests the presence of the transposed ascending aorta. They correlate pulmonary plethora and a concave left middle segment with a misplaced pulmonary artery. In a respectable number, the lung fields were normal or oligaemic, only tow of the cases having coincident pulmonary stenosis.

The findings by x-ray and fluoroscopy are set out in the table. No great variation from the reported findings is present, though occasional bulging of the left middle segment (as seen in the A.P. view) was present. Pulmonary plethora was invariable but no case of pulmonary stenosis was found at post-mortem, nor suspected by other means (angiocardiography). All cases had cardiac enlargement, though this was not very marked in case 97, who had a Bing-Taussig heart.

Little difficulty was met in recognizing the pattern at fluoroscopy, though in the very young infants, plain films showed pulmonary plethora to a better advantage. An essentially similar picture was seen in a case aged 2 weeks who was eventually found to have a truncus. This difficulty has been commented on by Astley and Parsons. The variation in radiological finding reported by these authors was not present in this series, perhaps because of the high mortality at an early age. The presence of a "long narrow segment" in the left middle zone has been seen once in another patient not here reported, in whom the diagnosis is still in doubt.

Angiocardiography

Five children were examined by this technique. Views were taken in the antero-posterior and oblique views, though not in the same patient. The latter was preferred, as the origin of the aorta is much more readily visible. Similarly, the take-off of the pulmonary artery is seen, a fact of considerable importance in the diagnosis of the Bing-Taussig phenomenon. Astley and Parsons remarked on the poor view of the pulmonary artery as seen in the antero-posterior position. Certain plain films and angiocardiograms are reproduced in the appendix.

Electrocardiography

Taussig states that right axis deviation is usual, and Keith and his associates found this in all of their 44 cases. Astley and Parsons (1952) noted peaked and enlarged 'P' waves in the standard limb leads, stating that the axis was variable, but usually to the right. They suggested that clockwise rdation about the axis was common.

In the cases here studied, the axis was to the right in all except one case. Definite strain pattern was observed in case 26, at the age of three years. Four of the thirteen cases showed 'peaking' of the 'P' waves (usually in lead II), only in one was this greater than 2.5 mm.

The pattern in most cases was indistinguishable from normal in young infants. The 'peaking' of the 'P' waves is common to tetralogy of Fallot and to tricuspid atresia, though of course left axis deviation is more common in the latter.

In fine, the electrocardiogram was of little value in the diagnosis of transposition of the great vessels.

Cardiac catheterization

Angiocardiography is probably the better mthod of definitive investigation in these cases, though Bing (1947) has shown the use of physiological investigation in the definition of the associated defects. Three children in this series (cases 121, 128, and 26) were subjected to cardiac catheterization. Full physiological study was impossible, as the pulmonary artery was not entered. It was possible however to adduce the presence of atrial septal defect by advancing the catheter into the left atrium. In one case four chambers and the aorta were entered. It was observed that the pressure in the chamber giving rise to the pulmonary artery was lower than the aortic chamber. Little other useful information was obtained, though a knowledge of the associated defects enables a more accurate prognosis to be given, and it is possible to differentiate the Bing-Taussig heart from other forms of transposition.

Prognosis

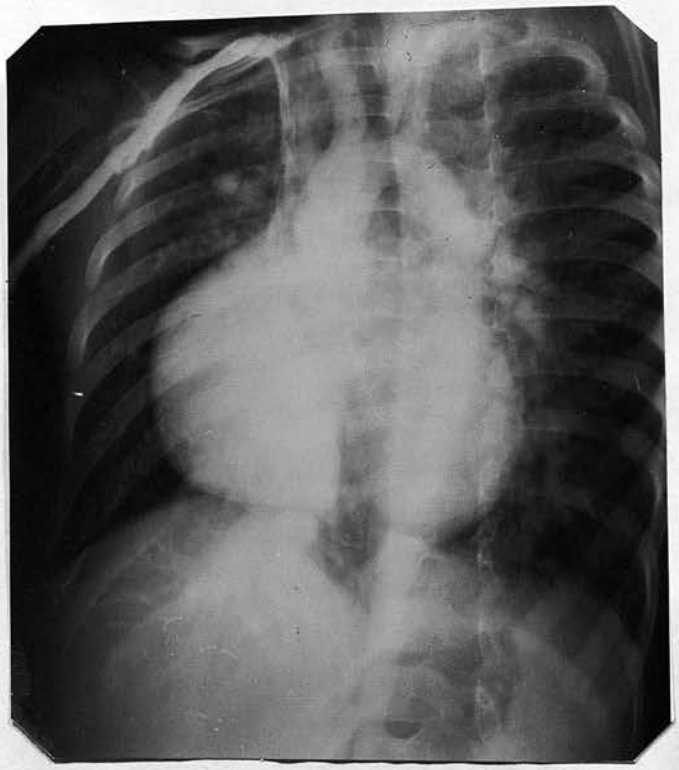
Keith (1953) states that the average age at death is 3 months, and almost 50% of his patients died while less than one month old. This gloomy picture is echoed in the present series, where only four of thirteen patients survived, the oldest being some $3\frac{1}{2}$ years of age at the time of writing. This child has been catheterized to show a large atrial septal defect and an associated ventricular septal defect, and doubtless these are the cause of her long survival. The lung-fields are hypervascular in this patient which excludes pulmonic stenosis. This contributes to a more efficient circulation.

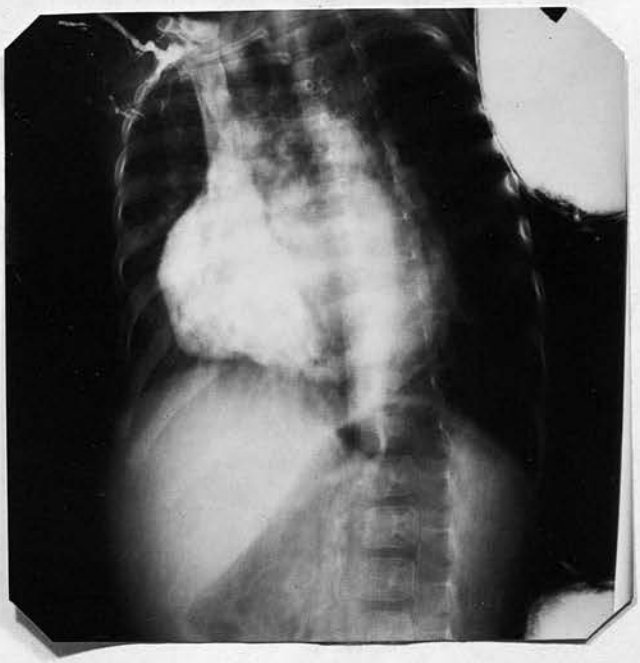
Management

Generally this is symptomatic, consisting in the adequate treatment of respiratory infections and congestive cardiac failure as the need arises. Prophylaxis by long-acting penicillin derivatives has its place.

Specific treatment for many of these cases would require radical reconstruction of the heart. Efforts have been directed by Blalock to increasing the shunt mechanisms, his most effective procedure being the anastomosis of the subclavian artery to a branch of the pulmonary artery together with the production of an atrial septal defect. Even this however has been of only fair value. Mustard (Keith et al 1953), has attempted repositioning of the vessels, using extra-corporeal circulation - a procedure which is promising but is complicated by the problem of maintaining the coronary circulation. Transfer of the pulmonary veins to the right heart, and of the venae cavae to the "left" heart is another possibility, though fraught with tremendous difficulties. In those cases showing pulmonary oligaemia Astley and Parsons have suggested that pulmonary valvotomy may be attempted.

TRANSPOSITION OF THE GREAT VESSELS

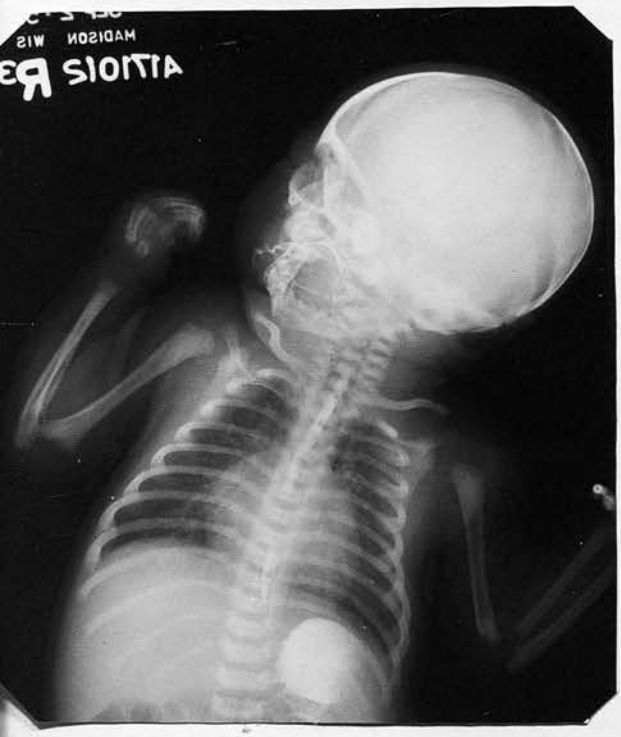




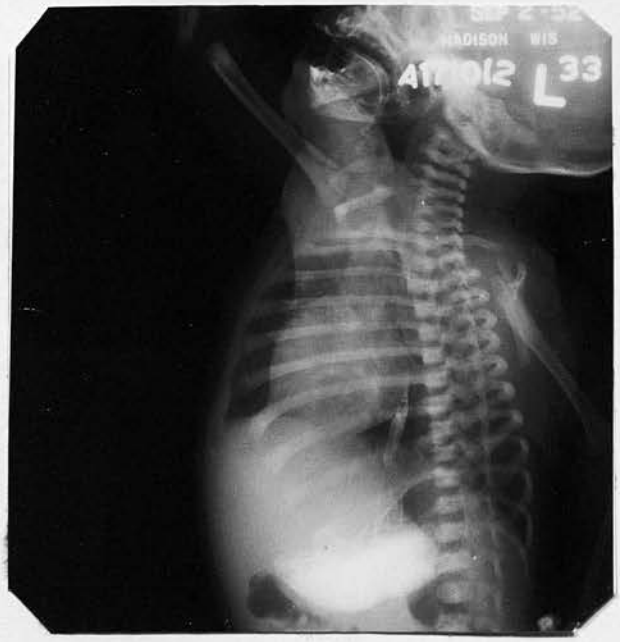
These angiocardiograms show the aorta rising from the right ventricle.

TRANSPOSITION - CHEST FILMS

P.A.

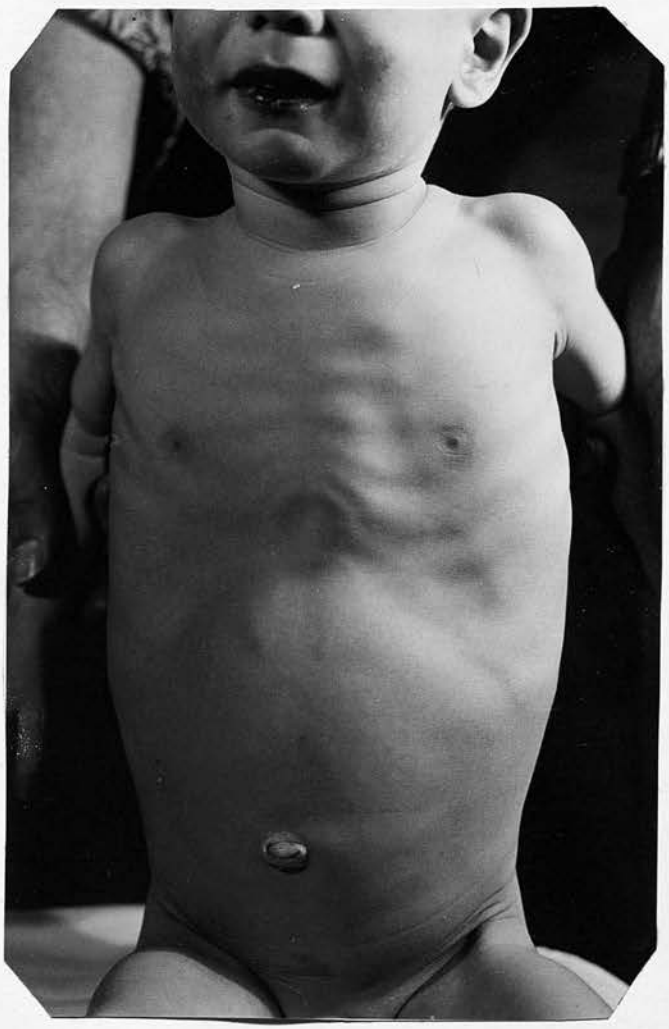


Left Oblique



Note the cardiac enlargment and plethoric lung fields. The vascular pedicle is narrow in the P.A., and increases on rotation.

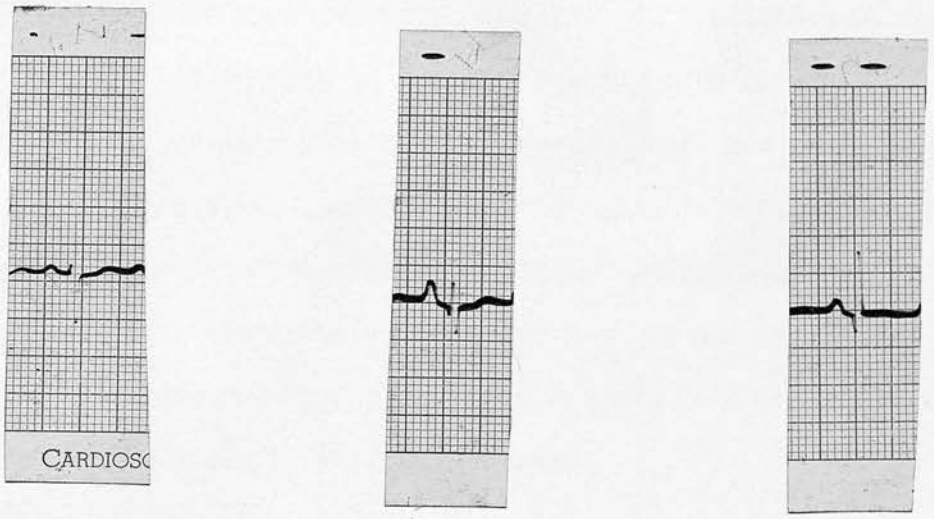
TRANSPOSITION



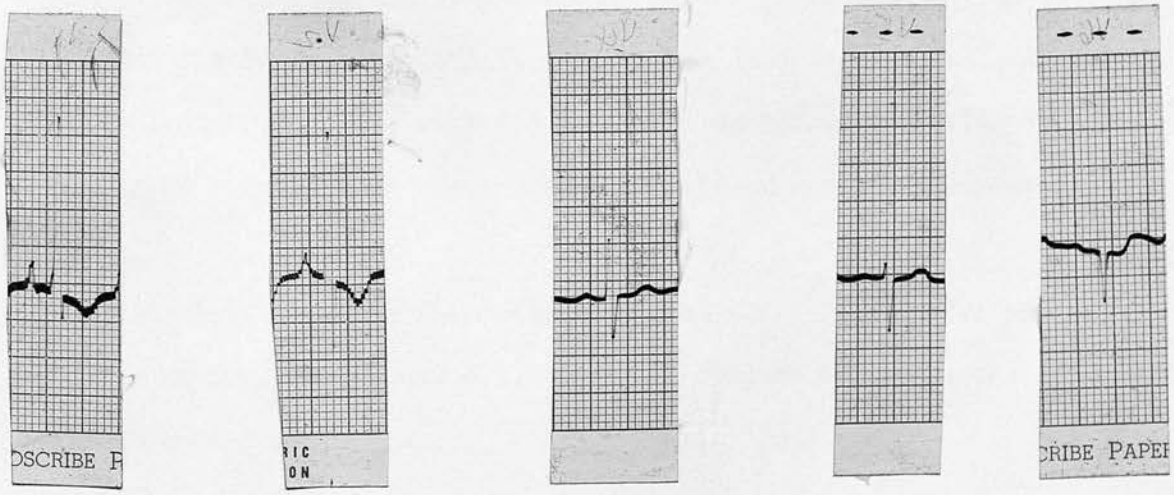
This plate illustrates the under-nourishment and chest deformity.

E.C.G. - TRANSPOSITION CASE 129 AGE 4 MONTHS

1 2 3



V 1 V 2 V 4 V 5 V 6



Note peaked 'P' waves in leads 2 and V_1; There is right ventricular preponderance which is physiological at this age.

Autopsy Reports

Case 182

S.V.C., I.V.C. and two pulmonary veins drain into the right atrium. The tricuspid valve appears normal and leads into a thickened right ventricle which gives rise to an aorta guarded by a normal valve and giving off two coronary vessels. Two (left) pulmonary veins enter a small left atrium communicating with a hypoplastic left ventricle via a tricuspid mitral valve. The pulmonary artery rises from this, and communicates with the aorta by a large patent ductus arteriosus. The ventricular septum was intact; the atrial septum was pierced by a foramen ovale guarded by a 'flap' membrane.

Case 215

Venae cavae to the right auricle which communicates with the left auricle by a large foramen secundum. The tricuspid valve is normal, and the right ventricle is hypertrophied. The aorta rises from this and its valve and coronary circulation seem normal. A small (0.5 cm) interventricular septal defect exists at the upper part of the septum. The pulmonary venous return is normal, the left atrium small, and communicating normally with a left ventricle which gives rise to the pulmonary artery. The brain showed widespread cerebral haemorrhages.

Case 129

Complete transposition with normal coronary circulation and pulmonary venous return. There was a large patent foramen secundum, and a recently closed ductus arteriosus.

Case 60

Complete transposition of the great vessels, the aorta giving off a single coronary only; the right ventricle was hypertrophied. A 1.0 cm. ventricular septal defect was present, together with a functionally patent foramen ovale. Pulmonary venous return was normal. The lungs

showed bronchopneumonia. An ileo-caecal intussusception had been the primary cause of death.

Case 51-99

Greatly enlarged heart, with the aorta rising anteriorly from a thickened right ventricle. This vessel gave off the coronary arteries. The pulmonary artery arose from the left ventricle; a patent ductus and anatomically patent foramen ovale were present.

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Section 5

PULMONARY STENOSIS WITH NORMAL AORTIC ROOT

PULMONARY STENOSIS WITH NORMAL AORTIC ROOT

While pulmonary stenosis, unassociated with the Tetralogy of Fallot, has been recognized since the time of Morgagni, the clinical importance of the condition was considerably under-estimated. Brock (1948), and Sellors (1948), by introducing a direct surgical attack on the diseased valve stimulated the search for cases. Accurate diagnosis of such conditions as atrial septal defect with pulmonary stenosis in distinction to the more common Tetralogy of Fallot became of importance when Brock and Campbell (1950) showed that congestive failure might follow an anastomotic operation in that condition.

Much discussion has centered about the nomenclature of the condition. The essential lesion is the stenosis, which may be isolated, associated with a defect of the auricular or ventricular septum, or complicated by a patent ductus arteriosus.

The various possibilities are summarized by Abrahams and Wood (1951) in their admirable article. Their nomenclature, and clinical division has the virtue of clarity and is adopted in this presentation.

The Stenosis

This is valvular, subvalvular, or infundibular in position. More than one type may co-exist in the same patient. The exact incidence is difficult to estimate especially if figures are based on autopsy material fixed in formalin. Brock (1952) observes cogently that although the outflow tract (infundibulum) is often hypoplastic, it is adequate in functional capacity. This may be much distorted after death.

Kirklin and his associates (1953) review reliable autopsy material, concluding that valvular stenosis occurred in some 74%, infundibular stenosis in 15%, and combined lesions in the remainder. In describing six specimens of their own, encroachment upon the lumen of the outflow tract by hypertrophied muscle bundles was found in each.

Brock (1948) described methods of recognizing each type by inspection at the time of surgery, and is prepared to carry out valvulotomy or infundibular resection as necessary. Preoperative diagnosis of the present and type of the lesion may be made by cardiac catheterization (Cournand et al., 1949), though Kirklin has shown that occasional errors may occur in the preoperative diagnosis.

Angiocardiography is also of value (Campbell and Hills 1950). Each method will be more fully discussed later.

Aetiology

Abbott, (1937) attributed 'pure' valvular stenosis to a foetal endocarditis, though the frequent association of misplaced leaflets and other serious cardiac defects is more typical of a developmental error. It has been suggested by Gross (1941) that a true inflammatory origin is unlikely.

Keith (1909) has proved that infundibular stenosis is due to an anomaly of involution of the bulbus cordis. Acquired valvular stenosis is rare, but two cases are figured by Abrahams and Wood (1951).

Material

Eighteen cases were seen in fourteen months. Four had intact septa; the remainder had septal defects, in only two was this located in the ventricular septum.

An additional case not here reported has been seen where a patent ductus complicated a valvular pulmonary stenosis. This is apparently a rare condition though such a case is reported by Abrahams and Wood (1951). The increased incidence of pulmonary stenosis is of interest; some of the cases studied here were mild, and probably would have been unrecognized except for the stimulus provided by haemodynamic investigation.

The cases here described have been mostly confirmed by cardiac catheterization. Therefore, it is proposed to consider the haemodynamic data first, and to relate this to the observed clinical phenomena.

Method of Diagnosis:

Pulmonary stenosis is characterized by right ventricular hypertension and a low pressure in the pulmonary artery. A pressure recording made while the catheter is withdrawn from the pulmonary artery to the right ventricle and atrium will show whether a valvular or infundibular lesion is present. The tracing obtained in the valvular type is seen opposite, that in infundibular stenosis is illustrated in the section on tetralogy of Fallot.

If the catheter is made to enter the left atrium, either a foramen ovale with a "flap" valve exists, or an atrial septal defect is present. It is not generally possible to be certain of the lesion, but its demonstration denotes the possibility of shunt reversal. The presence of a ventricular septal defect may be adduced if there is arterial contamination of the right ventricular blood specimens. If the aorta is entered, this argues that there is over-riding of the aorta in addition. This would exclude such cases from present consideration.

The Haemodynamic Possibilities

The paragraph on "Pathology" has mentioned the associated conditions of atrial and ventricular septal defect. Patent ductus is rare; the septa may be intact and the pulmonary valve only be affected. In this latter instance, there is no possibility of left to right shunt or vice versa. Symptoms therefore reflect the loss of functional reserve of the over-worked right ventricle.

Where the septa are breached, or a foramen ovale with a mobile 'valve' is present, several possibilities exist: the shunt may operate constantly in a left to right direction; transient reversal may occur as in exercise, or permanent reversal to the right may occur. In the latter instance cyanosis, clubbing, polycythaemia and dyspnoea will reflect the arterial unsaturation.

Examples of these possibilities will now be considered.

Pulmonary Stenosis with Intact Septa

Four such cases were studied; in two the diagnosis was confirmed by cardiac catheterization. One was diagnosed by angiocardiography, and one by clinical methods only. It is not always possible to say that a foramen ovale does not exist. Catheterization will occasionally give the opportunity to examine the left atrium. It has been the practice here thoroughly to explore the atrial septum in all cases of congenital heart disease. With this proviso in mind, the diagnosis of isolated pulmonary stenosis was made.

Symptoms

These were few. Generally the presenting complaint was of a 'murmur'; in one case frank exertional dyspnoea was present. Another tired easily. Other 'neurotic' phenomena occurred, generally due to ill-advised restriction of effort because of the murmur. A normal neonatal state was usual. Cyanosis at birth was not a feature. Only one child had a history of 'failure to thrive' in early life.

Signs

Growth was usually adequate. Bulging of the left upper chest was seen once. The pulses were always normal; in one case the heart was clinically enlarged. All cases had a systolic thrill maximal over the second and third left interspaces. This was accompanied by a loud systolic murmur maximal in the same area. This latter could be well heard in the left axilla and interscapular areas.

The second pulmonary sound was never split; in two it was single and presumably of aortic origin. In the remaining two, the 2nd sound was absent. A phonocardiogram is reproduced to illustrate these findings.

X-Rays

All cases showed some degree of cardiac enlargement, usually moderate. This was of right ventricular origin. The lung fields showed a variable decrease in vascularity. This was most obvious at the periphery of the

lung-fields. Post-stenotic dilatation of the pulmonary artery was universal in this group and is the most characteristic sign.

Electrocardiogram

All four cases showed right axis deviation. Two showed right ventricular preponderance. None showed an indubitable right ventricular 'strain' pattern.

Haemodynamics

The table opposite summarizes the findings in two typical cases. It is seen that the essential point is a right ventricular hypertension with a corresponding low mean pulmonary arterial pressure. The cardiac output remains relatively normal, but is accompanied by a great increase in right ventricular work (normal 0.89 Kg/M/min).

Since the septa are closed, no avenue exists for a right to left shunt. Thus the arterial saturation is normal. So then no case of pulmonary stenosis with closed septa will ever develop cyanosis of central origin nor its associated clubbing or polycythaemia: peripheral cyanosis is however observed.

Examination, both clinical and haemodynamic, failed to show the giant 'A' waves said to occur in the great veins in severe forms of this condition (Abrahams 1951). The moon facies was not seen either. The right ventricular pressures of course are not at a high level in the two examples quoted. In summary, the cases here described had few or no symptoms, and had characteristic clinical and radiological findings which were readily recognizable.

Pulmonary Stenosis with Atrial Septal Defect

Eleven such cases were studied. Ten were proven by cardiac catheterization, another at autopsy.

It is obvious in the face of a defect which is not guarded by a valve (foramen ovale), that a shunt may exist from left to right or from right to left. The direction of shunt may be clinically obvious by cyanosis, or may only be calculable at cardiac catheterization. It is

conceivable of course that a circumstance may occur where the right and left atrial pressures are so balanced that a suitable pressure gradient does not occur. A 'formula-sheet' as used in this laboratory for relevant calculations, is given in the appendix. The various types will now be considered.

Pulmonary Stenosis with Atrial Septal Defect and Right to Left Shunt

Six such cases are considered. The stenosis was valvular in all except one case.

Symptomatology

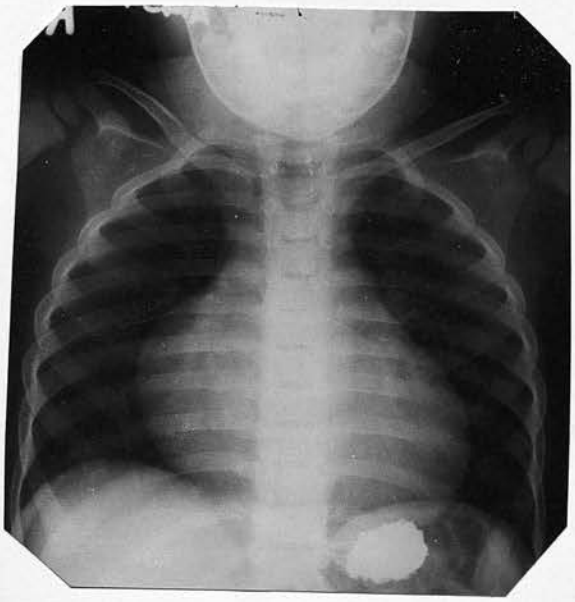
The birth state was said to be normal. A murmur and cyanosis were the usual leading complaints. The latter existed from birth or the first few months of life in 4 cases. In two it occurred after 2 years of age; in one of these cyanosis was exertional only. Dyspnoea at rest and limited exercise tolerance was present in five cases. Poor weight gain in infancy was described three times; frequent respiratory infections occurred twice. Five of these patients squatted, in three it was a frequent daily occurrence. One child had epistaxes.

It is obvious that difficulty in feeding and poor weight gain are rather less common in this condition than in the tetralogy of Fallot or isolated atrial septal defect. The early onset of cyanosis is at variance with the opinion of Allanby and Campbell (1949) who believe it occurs most often in the second and third decades. Again, the high incidence of squatting is quite opposed to the single case occurring in the series of Abrahams and Wood.

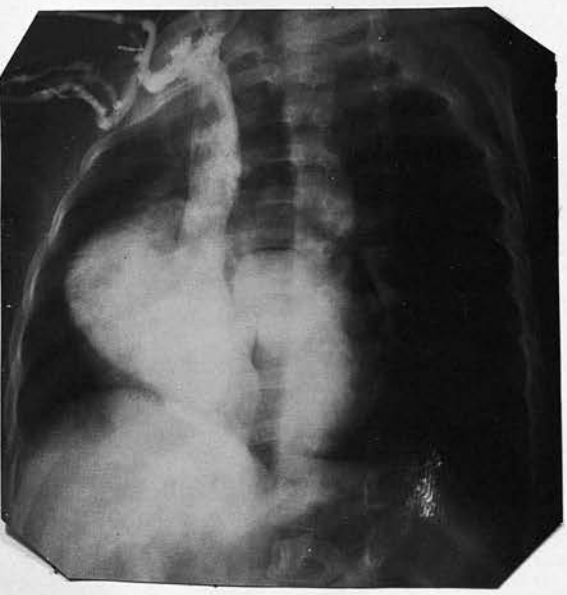
Each case was in the third percentile of growth. The "full" or "moon" facies noted by Wood (1950) was commoner in this group. An example is illustrated. As in many other types of congenital heart disease deformity of the chest was commonplace. In five patients the left upper chest segment bulged and associated Harrison's sulci occurred. In one case the sternum and both sides of the upper chest cavity were protruberant.

The signs associated with cardiovascular disturbance were of some

PULMONARY STENOSIS WITH ATRIAL SEPTAL DEFECT AND R TO L SHUNT



This P.A. film shows cardiac enlargement, prominence of the pulmonary arc and oligaemic lung fields.



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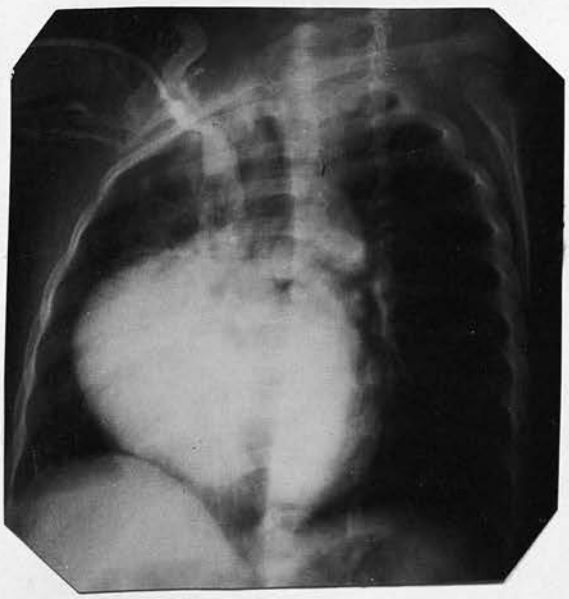

2.

These oblique angiocardiograms of the same case show the medium spilling into the left heart.

interest. Prominent neck veins with accentuated presystolic 'A' waves were common. This was not however directly related to the severity of the stenosis if this is assessed by the right ventricular pressure level. Thus one case showing this phenomenon had a right ventricular pressure of 64/0; another in whom it was absent had a level of 132/0. The pulse was normal in all cases. The apical impulse was right ventricular in type in each instance. Clinical cardiac enlargement was usual.

The systolic thrill tended to be more widespread between the 2nd to 4th interspaces. The localization to the lower spaces in infundibular stenosis was confirmed in the single case of this lesion which was encountered. The corresponding systolic murmur was transmitted to the left axilla and back. As in 'pure' pulmonary stenosis the second pulmonary sound at the pulmonary area was never split. In three cases it was weak or absent, in the remainder the second sound was loud but single. Clubbing occurred in five cases, paralleling the incidence of polycythaemia.

It is seen that this condition may be confused with the tetralogy of Fallot.

X-Rays

Cardiac enlargement was more severe in this group. Again the right ventricle was principally involved though a degree of right atrial enlargement was common. Except in the single case of infundibular stenosis, the pulmonary arc was convex. Pulmonary oligaemia was the rule. Four of the cases had a right sided aortic arch.

The individual findings are given in the later table. Certain chest films and an angiocardiogram are reproduced.

Electrocardiography

Right axis deviation was again invariable. High peaked 'P' waves occurred; definite right ventricular strain pattern was observed in several cases.

Cardiac Catheterization

Representative haemodynamic findings are given opposite. The same high pressure gradient exists from right ventricle to pulmonary artery as in the other forms. The arterial unsaturation reflects the right to left shunt.

Pulmonary Stenosis, Atrial Septal Defect with Bidirectional Shunt

This subdivision is based on haemodynamic data which are exemplified in the table. The direction of shunt is that of course existing under the investigative condition. Usually the child was anaesthetized. It does not reflect the clinical picture; the figures are calculated from the formulae given in the appendix. Four such cases were seen. In each the left atrium was entered by way of a defect or foramen ovale. In one was there significant depression of the saturation of the left atrial blood samples, so that a marked right to left shunt could not exist.

Clinically, only one case showed any cyanosis, and this was on exercise. The saturation levels confirm this. The signs were essentially those described for pulmonary stenosis with intact septa. Only the accident of left atrial catheterization made the diagnosis.

Pulmonary Stenosis with Left to Right Shunt

This is a curious haemodynamic condition fully recognizable only by cardiac catheterization. Fifteen cases are described by Abrahams and Wood (1951).

Four cases in children are included in this series. The catheterization findings are given opposite. In two the shunt was at the ventricular level; in one an atrial septal defect was present; in the other, a pulmonary vein was entered from the right atrium. Whether this was anomalous or had really been entered via the left atrium could not definitely be decided.

Clinically, these cases are asymptomatic. The complaint is always of a 'loud murmur'; growth and nutrition are normal. All four cases had loud basal systolic murmurs with coincidental thrills. The second

pulmonary sound was single in one, absent in one, and normally split in two others.

Radiologically, the heart showed moderate right ventricular enlargement in two. All had prominent pulmonary arcs. The lung vascularity was normal in two and increased in the others.

It is then seen that the signs are a blend of septal defect and pulmonary stenosis. In the two in whom the pulmonary second sound was split, the stenosis was unsuspected before catheterization.

The difference between the mean pulmonary arterial and the right ventricular pressures is typical of pulmonary stenosis. However no case of extreme right ventricular hypertension was encountered.

It is interesting to speculate how much the pulmonary stenosis exists as a compensatory mechanism to prevent a gross increase in the pulmonary flow. Certainly no case had a very large shunt when compared to some children with isolated atrial septal defect or patent ductus arteriosus.

General Summary

The cases here described were all seen in a short time - 14 months. The symptomatology is apparently entirely dependent on the presence of a septal defect. Cases in whom there is no septal defect have few symptoms. Exertional dyspnoea is the sole one of any importance.

Cyanosis, clubbing and polycythaemia reflect reversal of the shunt, but are not related to the severity of the stenosis as measured by the right ventricular pressure level.

The cardiac signs are common to all cases, as is seen from the context. The only exception are those in whom there is a left to right shunt. Here the second pulmonary sound may be split. Abrahams and Wood (1951) state that many of their cases with only mild right ventricular hypertension and closed septa have shown this splitting. This is not the experience of the present author.

Radiologically all cases show a prominent pulmonary arc. Moderate right ventricular enlargement occurs in many cases. Those children

with marked right to left shunts show the greatest increase in heart size. Right atrial enlargement is also common in these cases.

The pulmonary vascularity reflects the catheterization findings. Pulmonary oligaemia is severe in cases with right to left shunts. The lung fields are normal or mildly hypervascular where a left to right shunt occurs. In the intermediate cases with a bidirectional shunt, there is no relationship between right ventricular hypertension and the lung vascularity. Brock and Campbell (1950) found the aortic arch normal in their cases. Six of the cases examined in this series had a right aortic arch.

The electrocardiogram shows peaked 'P' waves and right ventricular dominance in the cyanotic cases. Those with left to right shunt have an occasional right bundle branch block - as in atrial septal defect.

The Haemodynamics

These are illustrated in the various lesions considered. Right ventricular hypertension of variable degree is the rule, and this results in an increase in the right ventricular work.

It is of interest to consider the genesis of the shunt reversal. Allanby and Campbell (1949), and Brock (1952) feel that the passage of time and severity of the stenosis causes this disabling complication. If this is true, then older children will have a greater tendency to cyanosis, equally, a severe rise in right ventricular pressure level will be associated if this is their criterion of the severity of the stenosis. Abrahams and Wood (1951) state that a high right atrial pressure is usual where the shunt is reversed.

In this series, these associations could not be confirmed. Thus one case age 12, had a right ventricular pressure of 215/-5; no cyanosis was present thought the left atrium was entered at catheterization. A cyanotic case age 3 years had a right ventricular pressure of 64/10; the right atrial pressure was 19/9 mm. Hg. Another cyanotic case, of the same age had an R.V. pressure of 75/-5; the right atrial pressure was

2/-1, which is normal. Another child with a right ventricular hypertension of 123/0 had a left to right shunt.

It is obvious then that the generalizations already quoted are untenable.

The reversal of the shunt then in some cases may be due to a rise in right atrial pressure. The absolute level is immaterial provided a right to left gradient exists. It has been shown that this is not necessarily dependent on the right ventricular pressure level. Apparently, from the data examined here, there is no relationship either between a low mean pulmonary arterial pressure and reversal of the shunt. It is possible that the low left atrial pressure consequent upon pulmonary hypotension is a factor.

Treatment

Surgical treatment by valvotomy was carried out in all cyanotic cases. No child with pulmonary stenosis and a left to right shunt was operated upon except one whose right ventricular pressure was 132/-4.

Generally an attempt was made to record pressures in the pulmonary artery and right ventricle at the time of operation. The results are noted in the table together with an analysis of the relief of symptoms.

Clinically the results were good. Those children who had been previously cyanotic and squatted, had marked relief. This occurred in spite of small or no relief of the right ventricular hypertension in some cases. The children who were without serious symptoms gained weight to a greater degree than might be expected. It was found that children in this group had in fact had some exertional limitation before operation. Only the post-operative improvement brought this to light. An similar phenomenon was reported in patent ductus by Gilchrist (1945). One case who had no fall in right ventricular pressure at the time of operation has been recatheterized to show a fall of 50%. All of the cases so far studied have maintained definite evidence of valvular obstruction in spite of a relief of symptoms.

Kirklin and his associates (1953) have commented on the difficulty of objective assessment improvement in adult patients. They feel that an adequate change in right ventricular pressure level is necessary for successful valvotomy. That this is not necessarily so is illustrated in the cases mentioned here. Swan (1954), has attacked the pulmonary valve under direct vision, and restored the right ventricular pressures to normal. It is possible that this is the treatment of choice, though the increased dangers of hypothermia must also be considered.

The cardiac signs remain essentially unchanged, as far as the systolic thrill and murmur are concerned. Four of six cyanotic cases suffering from atrial septal defect and pulmonary stenosis have developed diastolic murmurs. These are best heard at the middle of the left sternal border. The onset is variable. In one it was heard three months after surgery. In another its onset was delayed until ten months post-operatively. The onset of this murmur is not associated with increased cardiac enlargement, except in one case where a pericardial effusion was found. The murmur which is clinically suggestive of pulmonary incompetence is illustrated in the phonocardiogram. It is of some interest perhaps that this diastolic murmur has so far only occurred in cases with reversed shunt. Three other cases with atiral septal defect without reversed shunt have not developed this sign over the same follow-up period.

Summary

Pulmonary stenosis with and without septal defect is presented and discussed. Some results of surgical therapy are commented upon.

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Section 6

COARCTATION OF THE AORTA - ADULT TYPE

COARCTATION OF THE AORTA (ADULT TYPE)

Historical

Morgagni (1760) appears to have been the first to observe coarctation of the aorta, and Paris (1791) also reported a case. Mercier (1838) introduced the nomenclature. By 1928, Abbott had described 200 cases from the literature.

From the anatomical point of view, Evans (1933) made a full review of the possible types of stenosis and atresia of the aorta arch, though the shorter subdivisions of Bonnet (1903) into infantile and adult type is commonly in use. In the former, there is persistence of the foetal condition of the aorta as a diffuse narrowing of the isthmus, and in the latter there is an abrupt constriction at or near the point of insertion of the ductus arteriosus. This is the important clinical condition, though the actual constriction may be sited distal to the left carotid and proximal to the left subclavian.

Abbott (1928) notes that associated cardiac anomalies are often present in severe form in the infantile type, but that this is rare in the adult form, except for bicuspid aortic valve. The collateral circulation which is so prominent in this condition is mentioned early in the literature e.g. by Meckel (1830), and the subject has been fully discussed by Bramwell and Jones (1941); its importance lies in the recognition of the condition by clinical and radiological methods, besides of course the preservation of the integrity of the circulation.

The pathogenesis of the adult type of coarctation is classically that of Craigie (1841) who suggested that the process obliterating the ductus arteriosus involved the aorta and caused the constriction. This argues a post-natal development of the condition, and this is the opinion of Brown (1950). Some histological evidence is presented by Ascenzi (1947) who suggested that the middle elastic coat of the aorta is replaced by muscular tissue derived from the ductus arteriosus, and that subsequent excess of this strangled the aorta and caused the

condition.

Calodney and Carson (1950) state that the adult type was observed by Ingham (1939) in two foeti of 5½ and 6 months of gestation respectively, which suggests that the condition develops prenatally. Their explanation of the cause is that there is a defect in the development of the fourth aortic arch at its junction with the dorsal aorta and sixth aortic arch, which is the fore-runner of the ductus arteriosus.

Symptomatology

Most series concern adults; a typical paper is that of Christensen et alii (1948) who reviewed 96 cases. In these, the principal complaints were 'hypertension', dyspnoea, vertigo, palpitation, or occasionally, intermittent claudication or cerebro-vascular accidents; other authors, (Lewis 1933), have commented on the absence of symptoms, especially in the many service cases reported.

In children, it is necessary to exclude those who have essentially the 'infantile' condition, but a typical paper is that of Olney and Stephens (1950). They divide their cases into two groups. The very young, with principal complaints of dyspnoea and cardiac decompensation had high proportion of hypoplasia of the aortic arch, and two had mitral stenosis. The older, less severe group had a high percentage of intermittent claudication, and 3 of their 9 cases in this group were dyspnoeic on exercise.

The table (1) outlines the initial complaints, age, and sex of the short series presented. These contrast strongly with the adult symptomatology discussed above, and hardly agrees with group 2 of Olney and Stephens. These children were essentially symptomless; intermittent claudication was never present. Nearly all of the cases were suspected as a result of examination for some other abnormality. Case 78, in which the diagnosis was made by clinical methods only, may not be a "pure" one, and presented with dyspnoea as did case 44 which had a patent ductus arteriosus. "Tiredness in the legs" noted in case 20, might be expected to be a more

frequent complaint, though it has been shown (Lewis 1933; Wakim et alii 1948), that the difference in blood flow between the upper and lower limbs is insignificant in this condition. However, in one case (34), the mother was aware of a difference in temperature between the upper and lower limbs. The haematuria (and part of the hypertension doubtless) in case 96, was due to acute glomerulo-nephritis; that in case 240 was not explained in spite of adequate radiological and cystoscopic investigation. Epistaxes, noted by Brown (1950), to be a common symptom in childhood was found only once in this series (case 90). The predominance of the male sex echoes the findings of other authors (Gross 1953; Abbott 1928).

The clinical signs

The chief signs are shown in table 2. The growth, as expressed by the percentile level is usually good, although not all of the cases reflect the robust development reported by Taussig (1947). The poor growth noted in case 44 was due, to some extent, to the presence of a patent ductus arteriosus. Case 37 was the sole one in which the legs could be called "spindly". Pallor of the lower limbs was never observed. Two cases (37; 90), showed minimal abnormalities - increase in tortuosity of the vessels - on fundoscopy. There was no clear-cut instance of hypertensive change.

The sign par excellence is reduced or absent pulsation in the abdominal, femoral, or foot vessels, and was used in the diagnosis of the condition as long ago as 1835 by Legrand. Its importance has been emphasized by most authors on the subject (Lewis 1933; Bramwell 1947; Brown 1950). The latter author noted the importance of palpation of the femoral area in those children suspected of rheumatic heart disease; this is illustrated by case 37 who was followed for nearly 2 years as a possible rheumatic fever before the true diagnosis was entertained.

The table shows that this was an invaluable sign; where the femoral

pulses were present but weak, (case 96; 37; 20; 155; 44), palpation of the abdomen to check the abdominal aortic pulsation was a useful additional investigation. The delay in the femoral pulse was invariable.

The corollary to aortic coarctation is of course collateral circulation; this was remarked on by Meckel (1827), and described in masterly fashion by Lewis, and Bramwell and Jones, though Wernicke earlier included this in his criteria for the diagnosis of the disease. Brown (1950), in common with other authors, describes the collateral circulation as being most often clinically appreciable in the scapular and intercostal region; in this series, this was not a prominent sign except in the older age group. Cases 96, 37, 78, ages 2½ years, 3 months respectively did not show this sign at all on clinical examination, though evidence of collateral circulation (notched ribs) was present in case 96. This reflects the opinion of Sheldon (1945) who considered that the collateral circulation did not become clinically apparent until the 6th or 7th year; Bramwell (1947) however points out that "the superficial anastomosis is no sure indication of the extent of the anastomosis as a whole". In any case the absence of an obvious collateral circulation, even after using the manouevre of Suzman (1947) to exaggerate it, is of no importance in the diagnosis of coarctation in very young children.

Abnormally forceful arterial pulsation in the neck as described by Bramwell (1947) and others, was not common in this series, occurring in 2 of the older children only. This echoes the finding of Olney and Stephens (1950).

Brachial hypertension - clinical

This is of course a well-established sign, having been noted by Wernicke as one of his diagnostic definitives, though Bramwell (1947), states that it is occasionally absent. Lewis (1933), considered it dangerous to assume that the high pressure dated from the first year; Campbell and Suzman (1947) noted a steady rise of pressure between 5 and 19 years while commenting on the absence of data for children below

the age of 5. They also noted variation in the pressure level between the right and left arms, even when the origin of the left subclavian is above the coarctation; this they attribute to 'tortuosity of the arteries, or unnatural angles of flow of the blood stream'; Reifenstein et al. (1947) thought the difference due to the pressure of the distorted aorta on the left subclavian. Clinical observation shows that a difference between the right and left brachial artery pressures is common enough, and Gross (1953) considers that only a pressure difference of 30-40 mm. is significant.

The pressure levels are noted in table 3 and include preoperative and postoperative figures. It will be seen that hypertension can exist as early as $3\frac{1}{2}$ months (case 78); and in two other cases (37; 96), it was present at the age of 3 and 2 years; in the latter, haematuria due apparently to glomerulo-nephritis was present on the initial examination; during the course of follow-up, the renal lesions has healed, but the brachial hypertension has persisted. Brown (1950), has reported a 2 year old with hypertension.

The difference in level between the right and left arms has already been discussed above. The table shows that there is indeed a small but significant difference.

The pressure in the legs was unobtainable in all except 3 cases. The figures of femoral pressure are given in these. In one case (20), direct estimation was made by arterial puncture. The mean pressure in the brachial artery was 150, and in the femoral, 117 mm. of mercury. The tracing showed the typical delay of the femoral pulse, as reported by Lewis 1933, and by Wakim et al. 1948. The brachial pressure varied slightly from examination to examination, but never returned to normal. This phenomenon was also noted by Campbell and Suzman in their series, (principally adults).

The cause of the hypertension has been variably attributed to obstruction - the mechanistic theory. Others have suggested that the

rise in pressure is subsequent to renal factors (Page 1940), and due in essence to a Goldblatt kidney. The fall in pressure reported by some (Crafoord and Nylin 1945) goes some way to support the mechanistic theory.

In summary, it is seen that hypertension of a significant degree can arise early in life (as noted by Calodney and Carson), is variable during the period of observation but never returns to a normal level.

The bruit

Christensen et al. (1948), in their review of 96 (adult) cases of this condition noted that 94% of their patients had one or more murmurs, the most frequent being a rough systolic maximal over the base and in the interscapular areas. Bramwell (1947) considers that in some cases this latter site may be the area of maximal audibility. Campbell and Suzman (1947) come essentially to the same conclusion, though noting, as did Brown (1950) the occasional presence of diastolic murmurs in the absence of a patent ductus arteriosus. These have been seen principally in adults, and apparently may follow an attack of rheumatic fever, or of subacute bacterial ensocaditis. The incidence is as high as 20% (Christensen et al.).

The findings are noted in table 2. It will be seen that the murmur was systolic in all cases except one, where the typical Gibson murmur of an associated patent ductus arteriosus was present. A thrill was never felt; the murmur was loud in the scapular area in the older cases. The praecordial murmur showed no definite point of maximal audibility.

Heart size

The frequency of a normal heart size, as clinically appreciated, was observed by Lewis (1933), and confirmed by Campbell and Suzman (1947), and other authorities.

This was found in 3 of the 9 cases here presented, an incidence of 33% as compared with 7% reported by Christensen et alii, obviously this series is too short for definitive statistics. In cases 78 and 37, the enlargement had been noted radiologically early in life, at 3 months and 9 months respectively. The latter case is interesting in so far as

TABLE 4

		X-Ray Findings				E.C.G.	
Case	Age At Study	Cardiac Size A-P View	Chamber Enlargement	Rib Notching	Aorta	Axis Deviation	Strain Pattern
37	3 yrs	Enlarged	L.V.	No	Normal	Right	None
96	2½	Enlarged	L.V.	Yes	Normal	Normal	None
90	12	Normal	None	No	Asc. Aorta bulges	Normal	None
155	8	Enlarged	L.V.	No	Normal	Left	Left
78	3 mth	Enlarged	L.V.	No	Normal	Normal	None
29*	11	Normal	---	Yes	Aorta constricted as seen in L.A.O.	Normal	None
20	12	Sl. Enlarged	L.V.	No	Normal	Normal	None
240	11	Normal	Normal	No	Normal	Normal	None
44	10	Enlarged	L.V.	No	Not seen	Right	Right

*Angiocardiogram demonstrated site of constriction.

Contractions Employed

L.V. - Left ventricle
L.A.O. - Left anterior oblique

the cardiac size became proportionately less up to the age of 3 years, suggesting that the early hypertrophy was sufficient for activity thereafter. However, significant increase in size (radiological) between 3 and 3½ years led to a decision to excise the coarctation. In case 44, the enlargement was associated with the presence of a functioning ductus arteriosus. The cases were all checked radiologically, and no significant increase in heart size was seen except in those in which it was clinically appreciable.

The radiological findings

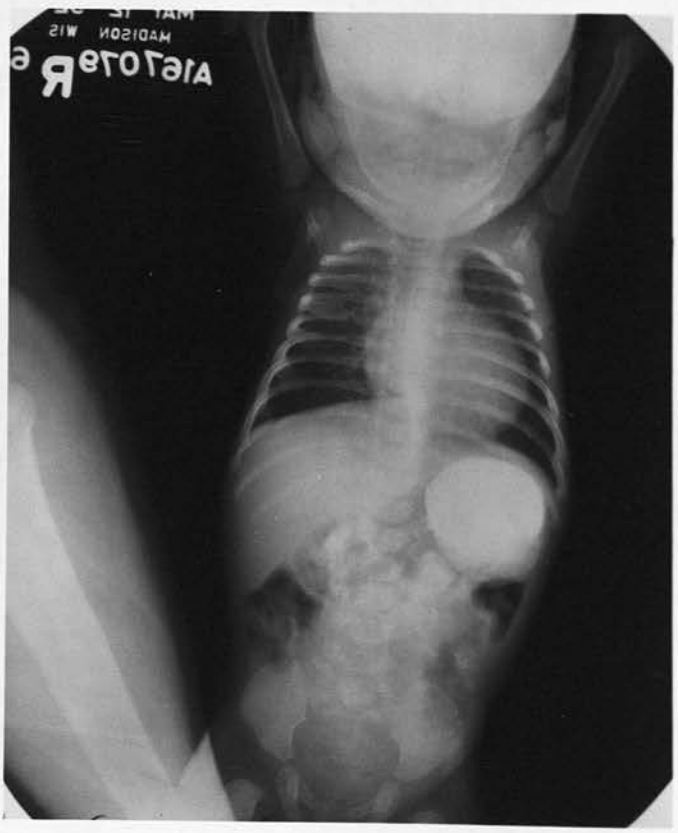
In adults these were well described by Lewis (1933). Gross (1953) summarizes this concept in children. The infant may show generalized cardiac enlargement, as in cases 37 and 78 here reported. He feels that up to ten years thereafter there is little abnormal in the radiograph except occasional evidence of left ventricular enlargement of small degree, or diminution in the aortic knob. Notching of the ribs has been an important method of diagnosis in the adult (Railsback and Dock 1929), and has been noted as early as the age of nine months (Neuhauser 1946). This sign was present in 3 cases, of this series, the youngest being 3½ years old. It is absent when a patent ductus arteriosus is associated (Evans 1933). Angiocardiography has been employed in the diagnosis of the condition (Dotter and Steinberg 1951), and also retrograde aortography - well illustrated by Olney and Stephens (1950). The former technique was used once (case 29), and readily demonstrated the site of coarctation.

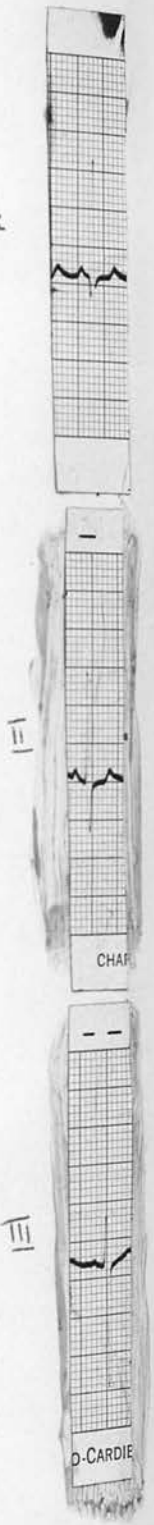
The table (4) summarizes the results of radiological investigation. Most cases showed a normal sized heart. The two cases where observations were made in infancy, including one complicated by patent ductus arteriosus showed increased heart size.

The electrocardiogram

Lewis (1933) considered - in adults - that left axis deviation was usual. Gross (1953) states that the electrocardiogram in children is usually normal; Brown (1950) thought that electrocardiography had little place in the diagnosis. The table (4) summarizes the findings in this series.

Case 78. Chest Film and Electrocardiogram (age 3 months).





X-Ray: Note enlargement of heart in A-P view. The contour suggests left ventricular enlargement. This was confirmed in the oblique view.

E.C.G.: Note left axis deviation.

One case of left axis deviation was seen at the age of $3\frac{1}{2}$ months - this is abnormal; in case 44 complicated by patency of the ductus, a right heart strain pattern was present.

The blood-count, Wasserman reaction, and non-protein nitrogen were normal. The Tuberculin test was invariably negative.

Complications

None was observed in this series. The position has been well defined by Gross (1953). Most complications, such as rupture of the aorta, or cerebro-vascular accident occur in adults, though an unusual case of rupture of the distal aorta was reported by France et alii (1950). Congestive cardiac failure has been reported in infants and young children by Calodney and Carson (1950), and Gross (1953). Concomitant thyrotoxicosis as noted by Cookson (1936) has been disclaimed by Reifenstein et alii (1947) as a true complication. It was not seen here.

Surgery

This was carried out on the majority of cases, and convalescence was generally uneventful. The femoral pulses if absent, became present, or increased in strength if previously palpable. The blood pressure was obtainable in the legs. It was noted that the legs became warm if a temperature difference had previously existed. The brachial pressure tended to fall in the immediate post-operative period, (in the absence of surgical shock) and then tended to increase. The table (3) notes the result of follow-up. In the cases followed the time interval varied from 3 months to 1 year post-operatively. The difference in pressure is not striking as far as the arms are concerned, but that of the legs shows normal or increased values. This is rather at variance with the result of others (Gross 1953) and suggests that in these cases there may be more than a mechanical factor in the genesis of the hypertension. The anomalous pressure in case 29 where the pressure in the left arm is lower than that in the right, where they were previously equal, was associated with an absent radial pulse. It was felt that some lesion of the left subclavian occurred as a result of surgery.

The murmur, observed over the same length of time, appeared in ost instances to be unchanged, and in case 155, the post-operative ocalization to the left interspaces suggested a septal defect. Cardiac atheterization was carried out three months after surgery, but the study as entirely physiological.

athology of the resected specimens

The gross and microscopic appearances have been well described by dwards et alii (1948). No unusual appearances were found in the specimens ere, most showing a localized atheromatous plaque.

ummary

Nine cases of coarctation of the aorta of the adult type are resented. All except two were operated upon. One was complicated by patent ductus arteriosus. The symptoms are reviewed, and the paucity hereof is remarked, the condition generally being found by accident. he sign par excellence is absence of, or weakening and delay in the emoral pulses, with brachial arterial hypertension. This confirming ewis's dictum for children also. Cardiac murmurs are non-specific, nd of little diagnostic value. Radiology and electrocardiography ontribute little. P$_o$st-operative persistence of brachial hypertension nd previous murmurs are noted.

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Section 7

ATRIAL SEPTAL DEFECT

Arteriovenous shunts, ventricular and auricular septal defects, and patent ductus arteriosus make up a large part of the material here presented, and will be dealt with together to some extent; as will be shown, the larger number of children were in the early years of life.

TABLE 1

AGE AND SEX DISTRIBUTION

	Male		Female	
0-6 months	4		11	
6-12 months	3		3	28 (68.2%)
13 months - 2 years	5		2	
3-6 years	2		4	
7-10 years	2		3	13 (31.8%)
11-13 years	-		2	
	16	+	25	41

Total = 41. Male 60.8%
Female 39.2%

ATRIAL SEPTAL DEFECT.

In the present survey, this is used as a 'blanket term' including such conditions as atrio-ventricularis communis and patent foramen ovale, since it is impossible except by autopsy to establish the exact site and size of the defect. It is however possible by cardiac catheterization to be sure that a communication does exist at the atrial level.

Historical

The condition was reported sporadically until the mid 19th century when Rokitansky published his epoch - making study; this contained a full pathological description of the various types of septal defects encountered, and proved them of true congenital origin. Abbott and Weiss (1928) described the clinical findings in cases proven at post-mortem, and commented on the typical 'gracile' appearance of these patients. Lutembacher described the syndrome which bears his name in 1916.

In 1934 Roesler published the clinical, radiological and electrocardiographic findings in a series of 62 patients and a careful study was presented by Papp, Bedford and Parkinson in 1941.

Cardiac catheterization by the method of Cournand and Ranges (1941) extended the diagnostic armamentarium; further precision became possible, both in simple confirmation of a clinical diagnosis and in the evaluation of the haemodynamics of the condition. (Brannon, Weens, and Warren 1945).

Atrial septal defects have come recently into the surgical orbit, successful closure having been reported by Swan (1953) and others. Experience with hypothermia and extra-corporeal circulation will extend this field (Bigelow 1950).

Age and sex incidence

Table 1 sets out the cases studied. It will be seen that there is a preponderance of females in this study, in keeping with the opinion of Abbott or Roesler, though the latter's study was of adult cases.

TABLE 2

LEADING SYMPTOM EXPRESSED BY MOTHER

Section A. Young Children (less than 18 months) - 27 Cases -

Symptom	Number of Cases
Poor Development	6
"Loss of voice"	6
Frequent cough or respiratory infection	5
Poor appetite	3
Cyanosis	2
Dyspnoea	1
Congestive failure	1
Pericarditis	1
Murmur	1
Enlarged heart	1

Section B. Older Children - 14 cases -

Symptom	Number of Cases
Murmur	7
Frequent respiratory infections	5
Fatigue	1
"Fast heart rate"	1

It is at variance with the equal incidence in fifteen cases recorded by Smull and Lamb (1952). This latter series, and the one presented here are much too short to allow of any definite deduction. The longer series of all types of septal defect given by MacMahon et alii (1953) gives an almost equal sex representation. This is probably the best estimate extant.

Almost 70% of the cases studied were under two years of age, and the larger proportion of these was in the early months of life. It is thought that these children are most worthy of close study in view of the opinion of Brown (1950), that the clinical picture in this group is still obscure.

Most of the papers already quoted, deal with the clinical phenomena in adults or older children. Thus the excellent paper of Barber, Magidson, and Wood (1950) contains only 5 children under the age of five years. It is hoped that the record of experiences presented here may help to high-light some of the earlier features of the condition.

Symptoms

Taussig (1947) in discussing atrial septal defects comments on the difficulty in diagnosis during the early months of life, though she states that frequent respiratory infection, and difficulty in gaining weight are predominant symptoms. These are not confined to atrial septal defect, but may be found in any left to right shunt, or for that matter in cyanotic congenital heart disease as discussed in the section on tetralogy of Fallot. Other features mentioned are paroxysmal tachycardias and the co-existence of mitral stenosis.

In this series (see tables 2 and 3) it will be seen that the majority of cases presenting in the first year of life have a leading complaint of respiratory infection, with failure to thrive as a good runner-up. A surprising number (six) presented with a complaint of "weakness of the voice", or variants; these are entered as 'laryngeal palsy'. Table 2 contains only the chief complaint as uttered by the mother, though most had been aware of "something abnormal"

TABLE 3

ANALYSIS OF ALL SYMPTOMS

Section A. Infant Group - 27 Cases -

Symptom	Number	Percentage
Poor appetite	24	88.8
Poor weight gain	23	85
Cough or respiratory infections	20	74
Dyspnoea	16	59
Cyanosis (all incidents)	16	59
Loss of voice (Laryngeal Palsy)	6	22
Tiredness or inactivity	4	14.8
Irritability	4	14.8
Mental retardation (3 mongols)	4	14.8
Congestive cardiac failure	2	14.8

Section B. Older Group - 14 Cases -

Symptom	Number	Percentage
Cough or respiratory infection	12	85
Poor appetite	9	64
Dyspnoea	9	64
Tiredness or inactivity	8	57
Failure to grow	7	50
Cyanosis (all occasions)	3	21
Congestive cardiac failure	1	7
Found on routine check	1	7
Pain in chest	1	7
Tachycardia	1	7
Epistaxes	1	7

in the child for a considerable time before arrival at hospital. It is worth-while comparing section A (table 2) with section B - the older age-group. In this latter, the condition was often unnoticed by the parents; the frequency with which a 'murmur at the heart' is the chief complaint shows that the condition was often found on routine examination - commonly for admission to school. The symptomatology is further broken down in table 3 section A, which deals with neonates and infants.

Taussig (1947) has pointed out that the cardiac dynamics existing at birth favour the development of cyanosis at this time. This occurred in 7 of the 41 cases, though the incidence may be too low in the older age group because of failure of parental memory. Blueness on exertion, or during a respiratory infection, - usually pneumonia following measles, - fully justifies the usage of "cyanosis tardive" in the clinical description of these children. It occurred in 16 of the 27 younger children. In no case was permanent cyanosis present, though this has been observed by the author in several adults. Cyanosis on crying may be very marked in infancy and lead to confusion with cases of tetralogy of Fallot.

It will be seen that frequent respiratory infection is almost invariable in the younger age-group. Usually it becomes a prominent symptom about the age of six weeks, but may begin in the first few days of life.

Generally the upper respiratory tract is involved. The child has an initial 'coryza' like syndrome, and this is shortly followed by a cough, occasionally accompanied by transient rhonchi. Fever may occur with the acute stage, but the condition clears rapidly with antibiotics. The cough remains however and will often continue until the next overt episode of 'tracheitis' or 'bronchitis'. This cycle recurs with considerable frequency; some mothers describe it as 'almost continuous'. Otitis media and tonsillitis occur with much less regularity. Cyanosis during coughing is a common sign

which distresses parents.

Serious infections, such as pneumonia are found to a much less extent. Few of the children were seen in the acute stage, the majority being treated at home or in the local hospital. It was possible however to identify 13 attacks of pneumonia among the 28 patients at risk. Three of these occurred in one child. Dyspnoea and cyanosis were much more prominent during these more severe respiratory infections. In general, these children made a ready recovery from the broncho-pneumonic episodes, though a chronic cough may follow.

It is difficult to assess the factors, apart from the presence of a shunt, which gives rise to these infections. Obviously a full-scale epidemiological investigation is impossible; it is also difficult to construct a control group adequate to balance social conditions and environmental factors such as the presence of sibling infection. A few cases of twinning occured in this and other types of shunt and it would appear that an normal twin will undergo only a small fraction of the respiratory infections. This is only a suggestion: the series is too short to allow a definite explanation.

Taussig (1947), and Smull and Lamb (1952) under-rate the importance of respiratory infections in atrial septal defect. This symptom is only equalled by failure of growth as the major symptoms in the younger sufferers. Both cause much parental misery.

Fortunately however, these children do not become 'fast' to antibiotics. Therefore it was thought useful to initiate some form of prophylaxis for the frequent respiratory infections. The agent chosen was a long-acting penicillin derivative (Bicillin), in a dose of 1,200,000 every four weeks. Again the short series followed makes definite opinions impossible, but the results seemed sufficiently encouraging to warrant further trial of the method. This is proceeding. An almost similar incidence of respiratory infections is found in

the older age group, though in many cases it was of greater degree during the first two years of life. Thereafter, the history shows that the 'almost continuous' occurrence falls to 'winter only', and the cough will clear up for long periods. Again however, severe lower respiratory infections will occur; in one case "pneumonia" was reported every year for 3 years.

To return to the younger children again, the general symptoms of failure to gain weight, poor appetite, tiredness and inactivity are very frequent (see table 3). The infant will take a long time to finish his feed, often refuses the bottle, or appears to be so breathless during sucking that the feed temporarily has to be abandoned. Much parental worry and effort is expended on ensuring an adequate caloric intake; when the time comes for weaning, this is difficult, and should be carried out with great caution. In the older group, this trouble in infancy is often carried forward as capriciousness of appetite in later years.

Irritability is common, though perhaps not so marked as in the cyanotic group (tetralogy) already described.

Dyspnoea

This usually presents as respiratory rate increased enough to take the mother's attention. It was a common symptom at rest in the infantile group. (see table 3). In one case (16), it was the presenting complaint. Usually it is aggravated by respiratory infection. In following these children it has become apparent that the importance of dyspnoea tends to be greater in the earlier months of life, falling off to a minimum (except during acute and moderately severe infections), about the age of one year. As activity increases, undue breathlessness on exertion appears, and, as the table shows, is a common trouble in the older group. This phenomenon appears to coincide with the falling off of frequent respiratory infection, and perhaps these factors may be related. Dyspnoea due to atelectasis following lower respiratory infection was found in cases 16 and 25 only.

Laryngeal palsy

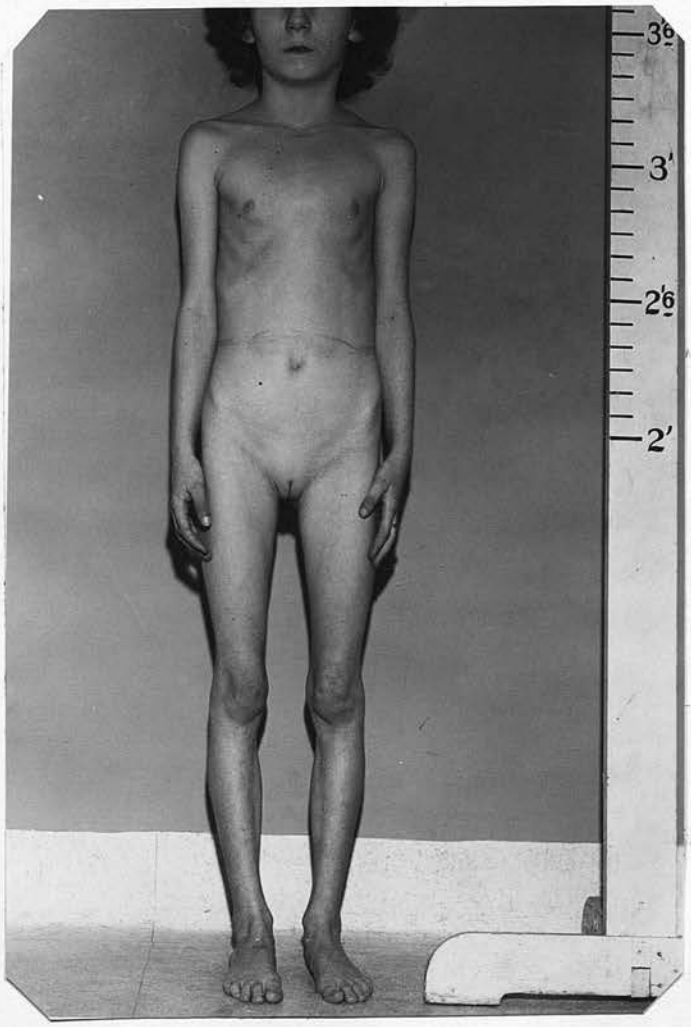
As already noted, this occurred in six of the infant cases. It is mentioned by Taussig (1947), and one of the cases described by Burrett and White (1945) - an adult - had the same complaint. Similarly 3 of the cases reported by Bedford, Papp, and Parkinson (1941) suffered from transient "hoarseness": two cases occurring in adults with atrial septal defect are presented by Erlanger and Levine (1943). Most series dealing with younger age groups do not mention laryngeal palsy as a symptom.

This condition is due to pressure on the recurrent laryngeal nerve between the greatly dilated pulmonary artery and the arch of the aorta. It occurred in cases 8, 13, 75, 134, 235, and 236; in each case the diagnosis was confirmed by direct laryngoscopy.

The syndrome, if it may be called such, is of interest; the age onset was in each case between five and seven weeks of age. Initially the voice is weak, not hoarse; the cry resembles a kitten's mew. Then in a little time, complete aphonia may appear. It is quite surprising to look down upon a child whose mouth is agape, eyes closed, face red with rage, and to hear no sounds issue forth.

The duration of the condition is variable; in case 134, the onset of aphonia was at 5 weeks, and this persisted until the age of six months. Case 235 began with weakness of the voice at 7 weeks of age, and the paralysis was still present at death when aged 6 months. Follow-up was impossible in 2 cases, but was more complete in case 8. In this child, weakness of the cry rapidly followed by loss of voice began at age six weeks. When examined at the age of four months she was quite aphonic, and laryngoscopy revealed total paralysis of the left vocal cord. There was no intervening period of hoarseness. Six months later, the voice was hoarse but audible on jabbering, but aphonia was present on hard "crying". At the age of thirteen months she could jabber and cry loudly in a hoarse voice. The condition was unchanged at age 16 months though a useful voice was present.

ATRIAL SEPTAL DEFECT: (CHILD AGE NINE YEARS)



Note the stunting of growth, gracile habitus, and deformed chest.

The investigation was followed through to autopsy in case 235. Careful dissection of the mediastinum revealed the recurrent laryngeal nerve to be nipped tightly between the huge pulmonary artery and the aorta. It was not involved in lymph-node enlargement. The larynx itself was free of infection. A section of nerve was removed and studied by microscopy, no cellular lesion was apparent in the sheath or the nerve fibres themselves. The findings here closely parallel those reported by Fetteroff and Norris in 1911. The history revealed episodes of hoarseness in early life in 2 of the older children; these were transient and no confirmation of the cause could be made. It would appear then that a weak or 'kittenish' cry, followed by loss of voice may occur fairly frequent in atrial septal defect. The onset of the symptom at the age of six weeks is perhaps related to the closure of the ductus arteriosus. A subsequent degree of shortening in the ligamentum arteriosum may help to co-apt the pulmonary artery and the aorta. Another possiblity is that a fall in pulmonary vascular resistance occurs at this time. This will increase the shunt and also the calibre of the pulmonary artery. A cough, brassy or not did not occur in 4 of the 6 infants, even in the presence of respiratory infection which is rather at variance with the opinion of Taussig (1947).

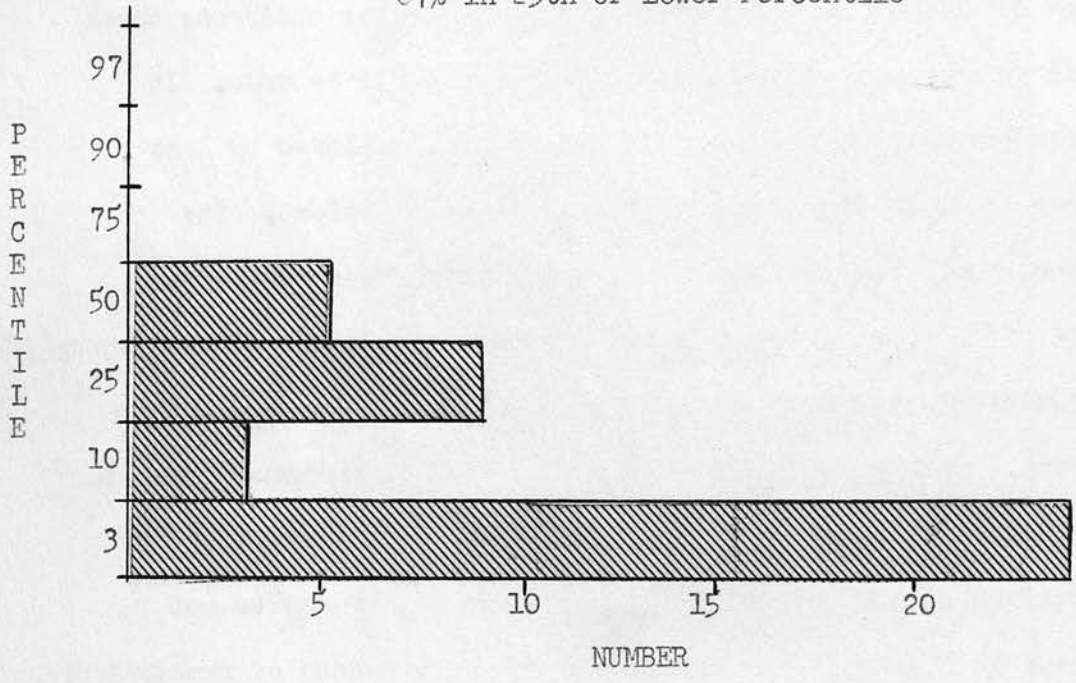
Less important symptoms in the younger age-group were: retardation in 4 cases, three of whom were mongols, the other a 'non-specific' mental defect. Slowness in passing the earlier milestones of development (holding up head, sitting up, walking), occurred in about 40% of the cases. Generally these children caught up by the age of two years. Two cases (110, 94), presented with congestive failure. Both had a previous history of frequent respiratory infection, dyspnoea, and failure to thrive. Only one case (180) presented with disturbance of cardiac rhythm, - in this case paroxysmal supra-ventricular tachycardia. This is a low incidence in comparison to the findings of Papp, Bedford, and Parkinson (1941), and Taussig (1947), but accords well with the findings of Smull and Lamb (1952).

TABLE 4

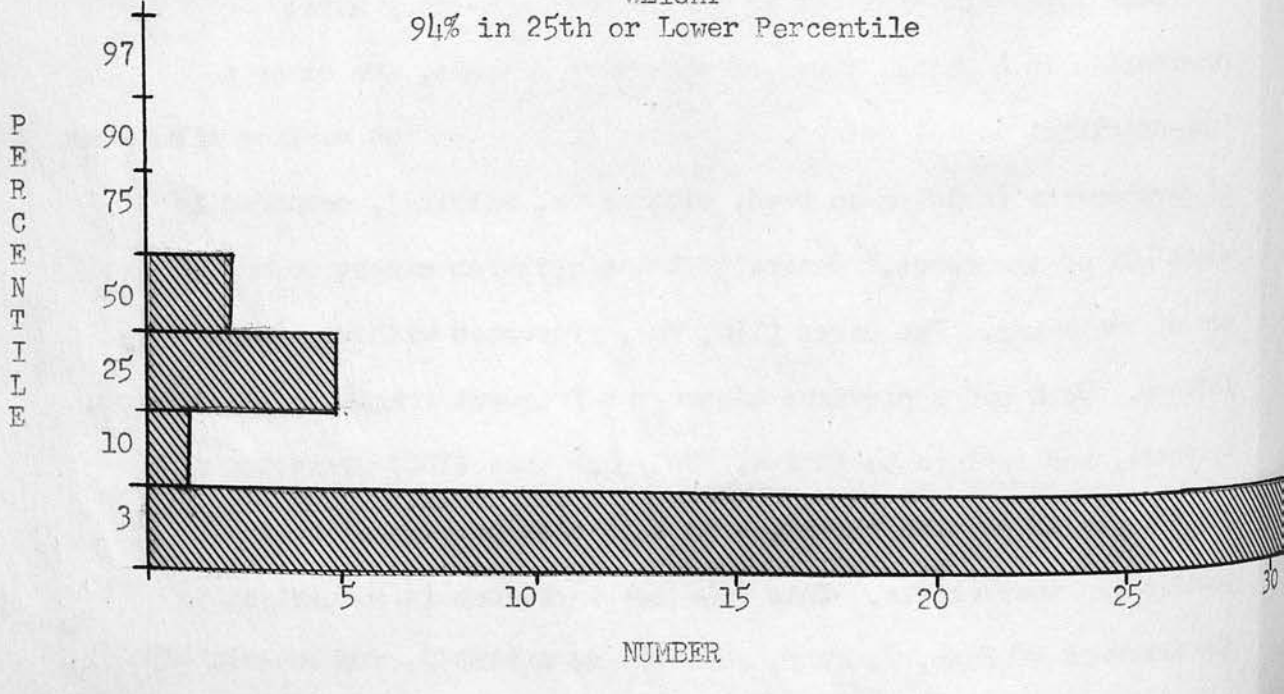
HEIGHT AND WEIGHT

PERCENTILE	3	10	25	50	75	90	97	
HEIGHT (41 CASES)	24	3	9	5	-	-	-	NUMBER
WEIGHT (38 CASES)	31	5	2	-	-	-	-	

HEIGHT
87% in 25th or Lower Percentile



WEIGHT
94% in 25th or Lower Percentile



The frequent association of arachnodactyly and atrial septal defect has been described by Futcher and Southworth (1938), and in one case (117), this was a symptom, the main complaint being deformity of the feet. The child was in fact suffering from arachnodactyly and arthrogryphosis multiplex congenita (see plate), lenticular changes were however absent. Other associated defects giving rise to complaint were: erythroblastosis and hypospadias (case 200), case 145 had cleft-palate and congenital cataract. Chest pain, not of anginal type occurred once (case 107), and epistaxis once (case 92).

The physical signs

General appearance

The colourful description by John Hunter, and the frail build described as 'gracile' by Abbott (1928) and emphasized by Taussig (1947) is thought to be typical in these children. This is illustrated in plate and appears to be more recognizable in the group aged three years or more. At a younger age the child may appear relatively well nourished, but inspection of the height and weight shows marked growth retardation. Pallor was rare except in some of the babies. The hair was usually thin and unhealthy looking, as often found in children with chronic ill-health from any cause.

Height and weight

The results concerning this group are shown in the table of percentile distribution; this illustrates the severe stunting of growth which occurs. The figures for height, weight run quite parallel. An individual height and weight chart for a case is appended to show a fairly typical growth pattern for this type of lesion.

Chest deformity

Taussig (1947) notes the great frequency with which a left-sided chest deformity occurs in atrial septal defect. It has already been shown in a previous section (tetralogy of Fallot), how common this lesion is in cyanotic congenital heart disease, and a similar

TABLE 5

CHEST DEFORMITIES

Case	Age At Which Deformity Inspected	Upper Left Bulge	Bilateral Bulge	Harrisons' Sulci
149	13/12		Yes	
103	6/12	Yes		Yes
24*	11/12	Yes		Unilateral (L)
8	14/12	Yes		
12	18/12		Yes	Yes
17	21/12	Yes		
46	1 year	Yes		Yes
50	18/12		Yes	Yes
104	13/12		Yes	
110	21/12	Yes		Yes
236	5/12	Yes		
102	1 year	Yes		
117	6 years	Yes		
92	1 year	Yes		Yes
5	6 years	Yes		
81	10 years	Yes		
86*	5 years	Yes		Yes
94	5 years	Yes		Yes
107	7 years	Yes		Yes
77	23/12		Yes	Yes
197	8 years	Yes		

* = Protuberant Sternum
Total 21 of 41 cases. (54%).

condition may be found in other types of intra or extra-cardiac shunt. However the period of follow-up, possible here allows for some detailed description of the unfolding of the sign. The table (5) describes the state of the chest deformity at various ages.

It will be seen that 21 of the 41 cases showed this sign. Eleven of the whole group were six months old or less at the time of recording, and did not show any deformity. All of those over 6 months remaining in the group aged 2 years or less showed some type of change in the chest skeleton. Only some 60% of those aged 3 years or more showed the changes. These children had less severe symptoms than the younger age groups, though all except two had enlarged hearts.

Bulging of the left upper chest was visible as early as 5 months in case 236 (whose heart was greatly enlarged), and a similar bulge, together with Harrisons' sulci were seen at six months of age in case 103. By 13 months of age, case 149 displayed bilateral bulging of the upper chest with prominent Harrisons' sulci. Pinching forward of the sternum at the level of the angle of Louis was seen twice. It is evident that an initial left-sided bulge may progress to a bilateral deformity, often occompanied by deep Harrisons' sulci, and occasionally by sternal prominence. The condition stops short on occasion even in the face of a large heart size as in case 92, whose heart was among the largest (assessed radiologically) in the series. Only a moderate bulge of the upper left chest was seen. This child was not seen until the age of 9 years, it is possible that great increase in the heart size did not occur until after the chest deformation had become relatively fixed. Naish (1948), has correlated chest deformity with respiratory infection. This common occurrence will therefore be a factor also.

The signs in the cardiovascular system

These are summarized in tables 6 and 7 which represent younger and older age groups respectively.

TABLE 6

CARDIOVASCULAR SIGNS IN THE YOUNGER AGE-GROUP

Case	Age	Heart size (Clinical)	Apex Type	Systolic Thrill	MURMUR			Second Pulm. Sound	Third Heart Sound
					Systolic	Maximal	Transmission		
200	7/12	+		+	Gr. 4	2-3LIS	C	1	
173	14/12	+			Gr. 2-3	2-3LIS	B	1	
149*	14/12	+		+	Gr. 2-3	2-3LIS	C	1	
146	5/12	+		+	Gr. 4	2-4LIS	C	2+	
145	3/12	+			Gr.3	2-3LIS	B	1	
91	6/12	+		+	Gr. 3	2-3LIS	A	1	
103	10/12	+	R.V.	+	Gr. 4	2-3LIS	C	1+	
74	7/12	+			Gr. 2-3	2RIS	B	1+	
32	2 yrs	+		+	Gr. 4	2-3LIS	C	1+	
25	6/12	+	R.V.	+	Gr. 4	2-5LIS	C	1+	
24	1 yr	+		+	Gr. 4	2-3LIS	C	1	
16	3/12	+		+	Gr. 4	2-4LIS	C	1	
14	3/12	+	'Tapping'	+	Gr. 4-5	2-3LIS	C	2+	
8	4/12	+			Gr. 2	2-3LIS	A	1	
12	3/12	-	R.V.	+	Gr. 3-4	2-3LIS	C	1+	+
17*	18/12	+	R.V.	+	Gr. 3-4	2-3LIS	C**	2+	
46	4/12	+	R.V.		Gr. 3	3 LIS	B	1	
50*	6/12	+	R.V.	+	Gr. 4	4 LIS	C **	2+	
75	2/12	-		+	Gr. 4	2 LIS	B	1	
110	21/12	++	R.V.	+	Gr. 4	2-4LIS	C**	2+	+
134	2/12	-		+	Gr. 4-5	2-3LIS	C	1	
141	2/12	+			Gr. 3	2-4LIS	B	1+	
235	4/12	++		+	Gr. 3	2-4LIS	B	1+	+
236	5/12	+	R.V.	+	Gr. 4	Apex	B**	1+	+

*Associated right bundle branch block. ** Also has apical diastolic murmur.
Gr = Grade. 1+ = single but accentuated. 2+ = Widely split. LIS=left interspace.
RV = right ventricular. A= localized to left praecordium. B=transmitted to right praecordium and left axilla. C=Transmitted to both axillae and the back.

The pulse

Taussig (1947), comments that the pulse is generally normal; Brown (1950) notes that fibrillation occurs only if the lesion is complicated by mitral stenosis or hypertension. No abnormality of the pulse was seen in this series except paroxysmal tachycardia in one case. The left radial in case 42 was absent. There are several possible explanations for this curious finding. An anomaly of the left subclavian artery may be present. Hotz (1923) reported a case with similar findings. His explanation was that pressure from a huge pulmonary artery had affected the aortic arch. His case was additionally complicated by a recurrent laryngeal palsy. The larynx in the present case was normal. The true explanation is as yet obscure.

Praecordial examination

As already noted there may be deformity of the chest. The type of apical impulse found in atrial septal defect is of considerable clinical interest and importance. Roesler (1934), showed that a circumscribed powerful thrust at the apex was typical of atrial septal defect. Barber, Magidson, and Wood have observed a similar phenomenon in some cases of patent ductus arteriosus, and while admitting that this apical type occurred in their series, state that in the majority the impulse was 'tapping' (as in mitral stenosis). The character of the impulse was carefully considered and recorded in this series. Some 13 of the 21 cases examined early in life had what was interpreted as a 'normal' apex. Seven had a considerable localized powerful thrust, which was considered to represent the finding of Roesler (1934), and to be 'tumultuous' in the sense used by Barber, Magidson and Wood (1950). An essentially similar proportion was found in the older age group.

It is difficult to be sure that one can transfer to the child the description of an apex beat whose characteristics have been found in adults. The poor nutrition of these infants and children make the chest wall much thinner, and the apex beat more readily palpable or

TABLE 7

CARDIOVASCULAR SIGNS - OLDER AGE GROUP

Case	Age	Heart size (Clinical)	Apex Type	Systolic Thrill	Systolic	Maximal	Transmission	Second Pulm. Sound	Third Heart Sound
117	10 yr	+		+	Gr. 4	2-3LIS	C**	2+	
56	8 yr				Gr. 3	3-4LIS	C	2+	+
199	9 yr	+	R.V.	+	Gr. 4	2-4LIS	B	2+	
180	11 yr	+	R.V.	+	Gr. 5	2-3LIS	C**	2+	
42	8 yr	+	R.V.	+	Gr. 4	2-4LIS	C**	2+	+
89	6 yr			+	Gr. 4	2-3LIS	B	2+	
5	5 yr	+		+	Gr. 4	2-3LIS	B**	2+	+
81	5 yr	+		+	Gr. 4	2-3LIS	C	1+	
86	5 yr			+	Gr. 4	2-3LIS	C	1+	
94	4½ yr	+	R.V.	+	Gr. 4	2-3LIS	C**	2+	+
107	10 yr	+	R.V.	+	Gr. 5	2-4LIS	C**	2+	+
197	6 yr	+	R.V.	+	Gr. 4	2-3LIS	B	2+	
77*	2½ yr	+	R.V.	+	Gr. 3-4	2-4LIS	C**	2+	+
156*	12 yr	+		+	Gr. 5	2-4LIS	C**	2+	

*Associated right bundle branch block. **Also has apical diastolic murmur.
Gr = Grade. 1+ = single but accentuated. 2+ = Widely split. LIS=left interspace.
RV = right ventricular. A=localized to left praecordium. B=transmitted to right praecordium and left axilla. C=transmitted to both axillae and the back.

'powerful', and this may exaggerate the incidence of the 'tumltuous' apex beat in this group. However, comparison of the apex beat with normal children and within the group itself would in the author's mind tend to confirm this sign as a useful and common one.

Heart size

This was estimated by the displacement of the apex beat to the left and downwards. In the younger group percussion was also employed. The majority of these cases show displacement of the apex, and thus cardiac enlargement. This can be very marked as in cases 235 and 42, where the apical impulse was in the anterior axillary line.

Praecordial thrills

These are usually present if sufficiently searched for. The young infant may need palpation in the prone position, the older children should be examined when bending forward for when canted to the left. In the infant the thrill is best felt at the mid left sternal border, but fairly wide transmission over the chest wall and down to the xiphoid process may occur. Most commonly of course, it is felt where the murmur is maximally audible. An essentially similar incidence is found in the older group. The thrill is more localized to the mid left sternal border.

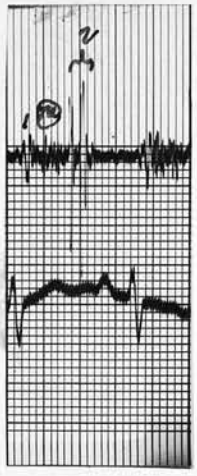
Murmurs

Systolic

A systolic murmur was invariable in the children studied. It was generally loud (the grading given is 1-6 of the American Heart Association); the transmission of the murmur, and point of maximal adubility are also described in the table. The latter was usually about a just above the mid-sternal area of the left praecordium. As usual, a more definite opinion could be expressed in the older age group; the thin chest wall and relatively large heart militating against great accuracy in the infant. As a general rule the murmur was best heard in the upper interspaces but, as will be seen later, differentiation by localization of the murmur in cases of shunt due

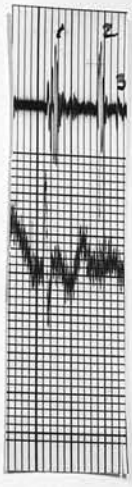
PHONOCARDIOGRAMS - ATRIAL SEPTAL DEFECT

1 - 2nd left interspace



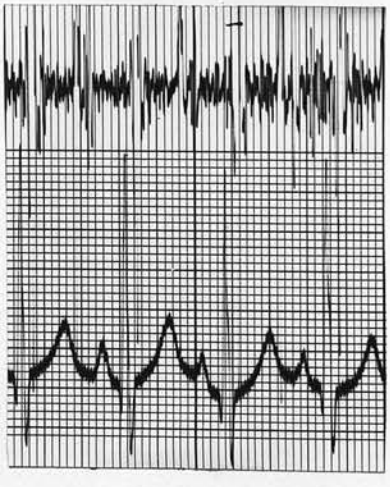
1. Systolic murmur and split 2nd sound

2 - 4th left interspace



2. Shows a loud third heart sound

3 - Apex



This tracing shows systolic and diastolic murmurs.

to lesions other than atrial septal defect is unreliable.

The diastolic murmur

Most diastolic murmurs found in atrial septal defect are attributed to associated mitral stenosis (Taussig 1947, Papp, Bedford and Parkinson 1941). Recently Barber, Magidson and Wood (1950) have described two type of diastolic murmur in atrial septal defect. One is an early diastolic best heard along the left parasternal border, and attributed to pulmonary incompetence, the other is a rumbling presystolic or mid-diastolic murmur heard at the apex. The first has a high overall incidence in their series, and was found in 3 of 5 cases aged 10 years or less.

Similarly Nadas and Alimurung (1952) in a review of 100 cases of non-cyanotic congenital heart disease found that apical diastolic murmurs were rather common. Usually the murmur occupied mid-diastole, only rarely was it presystolic. Their cases were fully investigated by cardiac catheterization and in some instances at autopsy. The table shows the mid-diastolic apical murmurs are quite common in atrial septal defect, especially in the older age-group here presented, where it was found in 9 of 14 cases.

Nadas and Alimurung (1952) in their paper are at pains to show that Lutembacher's syndrome is a rarity on the autopsy table and extend their thesis to consider that it is equally rare clinically. This is certainly so in the present author's opinion; a mid-diastolic murmur does not mean an associated mitral stenosis. This sign was found in case 110, in whom no mitral lesion was found at autopsy. Of the others in whom a mid-diastolic murmur was present, there was no anamnestic evidence of rhuematic fever, and in several cases the age at which the murmur appeared would be below that in which rheumatic fever occurs. From a physiological point of view, cardiac catheterization will help further to elucidate this problem. If the catheter is introduced through the atrial septal defect, and fed into the left ventricle, examination of the end-diastolic pressure of the left

atrium and left ventricle should indicate whether mitral stenosis is present or not. This was accomplished in several cases in whom a mid-diastolic murmur was present; no evidence of mitral stenosis was found. This conforms with results reported by Nadas and Alimurung (1952).

In conclusion it may be said that apical mid-diastolic murmurs occur frequently in atrial septal defect, and in some cases there is no evidence whatsoever of mitral stenosis. Mitral stenosis complicating atrial septal defect appears to have been greatly exagerrated. No clinical evidence of mitral stenosis such as opening snap, or a true presystolic murmur was ever found in this series.

Parasternal mid-diastolic murmurs, said to be typical of pulmonary incompetence were uncommon in this series, occurring only twice in the 14 older children.

The appendix gives the phonocardiograms of certain of these cases.

The pulmonary second sound (see tables 6 and 7)

Barber, Magidson and Wood (1950) found the pulmonary second sound to be widely split in the larger portion of their patients. This they attributed to bundle-branch block or to delay in the emptying time of the over-filled right ventricle. It has been long known that reduplication of the second sound is physiological in many children, and Barber and his collaborators found this to be invariable in the control group examined. They described three grades of splitting: Grade 1, where the split is hardly audible; grade 2 where it is well defined but the two sounds are close and grade 3 where the splitting is wide.

A control series examined personally, made up of children without historical, clinical, or x-ray evidence of cardiovascular disease showed that in the first 9 months of life the second sound is single in a high proportion of cases. Grade 1 splitting as defined above was present in the remainder, usually obvious only at the end of inspiration. After the age of 1 year, both grade 1 or grade 2

splitting is almost invariable. Accentuation of the second sound may occur in pulmonary hypertension also (Wood 1951).

With these facts in mind it is interesting to survey the table (7). which presents the data concerning the second sound. The symbol 2+ means that the second sound shows a grade 3 splitting. The asterisk indicates the presence of bundle-branch block. It will be seen that 7 of the 26 children showed this sign; in the older group, it was present in eleven of fourteen cases. There is a close association with the incidence of bundle-branch block in this age-group also.

Smull and Lamb (1952) noted that wide splitting of the second sound was uncommon in their series, they attributed this to the youth of their patients. The series here presented suggests that the incidence of widely split second sound rises with age, though it was seen as early as 5 months (case 146).

The third heart sound

This sign, first described by Gibson (1907), and following the normal second sound is said to be common in children but not in infants (Wood 1950).

Barber et alii (1950), found this sign at the apex, or lower left sternal border in 26 of their 62 patients, some of whom had mitral stenosis. It was sought for and recorded in this series. The table shows it to be the exception in the younger age group, but to be common in the older group. This contrasts with the finding of Barber, Magidson and Wood (1950) who found it only once in 5 children under the age of ten years. The impression, after survey of a control group of children is that, in the absence of moderate or severe anaemia, a third heart sound seems more common in atrial septal defect (and other left to right shunts), than in normal children.

Summary

In the group presented, the auscultatory findings were: a loud systolic murmur and thrill in the high left interspaces, often with a widely split pulmonary second sound, and a loud third heart sound.

TABLE 8

X-RAYS

Case	Age	General Cardiac Enlargement	Chamber Enlargement	P.A. Segment	Lung Vascularity	Angiocardiogra
200	8/12	+	RV	+	+++	
173	7/12	++	RV;RA	+	+	
149	2/12	++	RV	+	+	
146	5/12	+	RV	+		Yes
145	3/12	+				Yes
91	6/12	++	RV	+		Yes
103	3/12	Globular +	RV	+	+	
74	3/12	+	RV	+	++	Yes
32	3 yr	++	RV;RA	+	++	Yes
25	6/12	++	RV	+	++	
24	11/12	++	RV	++	++	
16	3/12	++	LA;RV	+	++	
14	3/12	++	RV;RA	+	++	Yes
8	5/12	+	RV	+	+	
12	3/12	++	RV	+	++	
13	6/12	++	RV	+	++	
17	16/12	++	LA;LV;RV	+	++	Yes
46	1 yr	+	RV	+	+	Yes
50	6/12	+	RV	+	+	Yes
75	3/12		RV	+	+	
104	13/12	+	RV	+	+	
110	23/12	+++	RV;LV	++	+	
134	6/12		RV			
141	3/12	++	RV;LA	+	+	
235	3/12	+++	RV;LV	+	+	
236	3/12	++	RV;RA	+	++	Yes
102	13/12	++	RV;LA	++	++	Yes
89	7 yrs			+		Yes
77	16/12	+	RV	+	+	Yes
197	6 yrs	+	RV	+	++	Yes
107	7 yrs	++	RV;LA	++	++	
94	5 yrs	+++	RV;RA;LV	++	+++	
180	11 yrs			+	+	Yes
199	9 yrs	+	RV	++	++	
56	8 yrs	+	RV	+	+	
86	7 yrs	+	RA;RV	+	+	Yes
81	10 yrs	++	RV;RA	+	++	
5	5 yrs	+	RV	+	+	
92	9 yrs	++	RV;RA	++	++	
156	11 yrs			+	++	
117	10 yrs	++	RV	+	++	

Diastolic murmurs are common. There was a suggestive relationship of the widely split pulmonary second sound to bundle branch block.

The special investigations

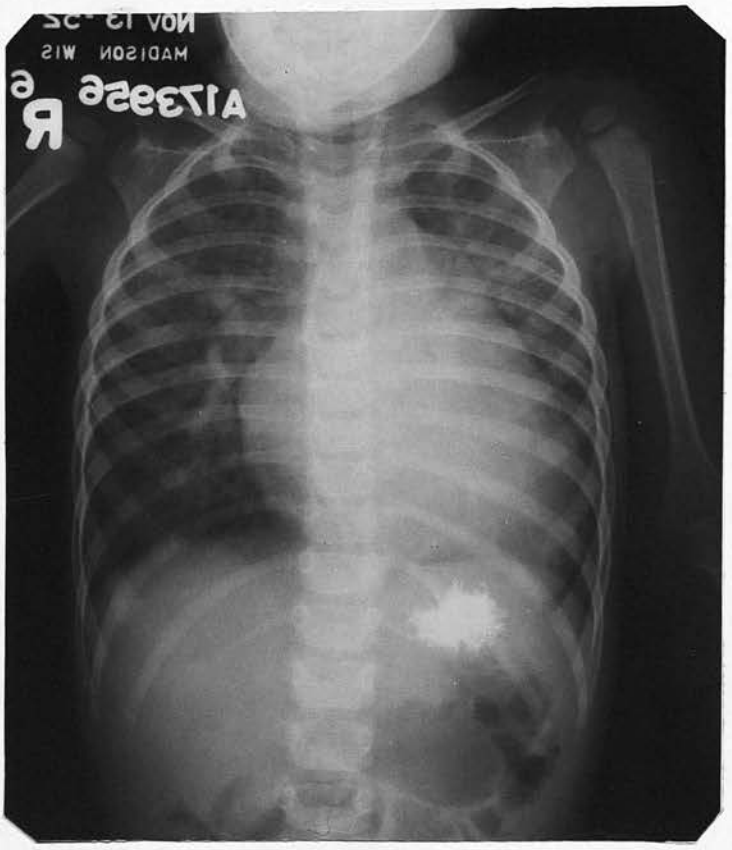
Radiology (including angiocardiography)

Assman (1928) noted the enlargement of the pulmonary artery and its branches. Papp, Bedford and Parkinson (1941) described as typical an increase of the right auricle and ventricle together with the prominent pulmonary conus and large dense main branches of the pulmonary artery. The lung fields are congested, and the aortic knob small. Similar findings are described by Taussig (1947). The principal radiological findings are expressed in the table (8). The results are those found in the groups under and over two years of age. It will be seen that there was obvious cardiac enlargement in all of the younger children and in all except three of the older group. This enlargement might reach huge proportions (cases 236, 102, 235, 110), the last two were complicated by congestive cardiac failure.

Chamber enlargement was almost always right ventricular, though the right auricle was appreciably enlarged in approximately one quarter. Those cases showing congestive cardiac failure (235, 110, 94), showed enlargement of the left ventricle as viewed in the left anterior oblique, case 17 was similar, here it was thought that the left ventricle was displaced posteriorly by the right ventricle, the size of the latter being assessed by the position of the inter-ventricular groove and, at a later date, by angiocardiography. Prominence of the pulmonary arc was likewise a usual finding and in the older children especially the main branches were often equally dense and prominent.

Hypervascularity was almost invariable, case 145 did not show this sign on examination at 3 months of age, but follow-up has revealed increased vascularity by the age of nine months. Pulsation strong enough to be called 'hilar dance' was seen in cases 81 and 107, though the pulsations in the inner lung fields were readily visible in almost all cases.

ATRIAL SEPTAL DEFECT



P.A. View: The film shows the marked cardiac enlargement - confirmed as right ventricular in the oblique views. The huge pulmonary conus and increased lung vascularity are well seen.

Several plates are attached to show examples of the radiological findings in this series.

Angiocardiography

Except in the rare case where an intra-cardiac shunt is reversed, injection of contrast medium into the venae cavae (usually the superior) has little chance of demonstrating the site of the defect. This is the opinion of Dotter and Steinberg (1951) though they relent sufficiently to say that this may not hold good in the young infant: here the pressure-level in the right atrium may be sufficiently raised by the force of injection accurately to demonstrate the defect. Another objection is that a functionally closed foramen ovale may be momentarily opened thus giving an erroneous impression. Early opacification of the left side of the heart and aorta may be considered presumptive evidence of an intra-cardiac shunt.

With regard to the problem of temporary reversal of flow through a foramen ovale, the interpretation of an angiocardiogram in this circumstance will be modified by the knowledge of fluoroscopy. If much hypervascularity of the lung fields is visible, if the pulmonary arteries seem dilated, and if the child has symptoms typical of a left to right shunt, the diagnosis of a foramen ovale, functioning so as to prevent such a shunt, but mobile enough to be displaced by injection must be discarded.

With these points in mind, the value of angiocardiography in this series will be discussed. In the infant group, twelve cases were subjected to this manoevre. Death occurred unfortunately in one case (the only one of all the cases in this thesis). All except two were age one year or less, the majority being around six months.

The recorded results are given in the appendix. Generally it was found that this method of investigation was of considerable utility in demonstrating a shunt, but only in the very young child. In certain of the cases it was possible to see the stream of contrast medium going from the right to the left atrium with subsequent opacification of whole

ATRIAL SEPTAL DEFECT

- ANGIOCARDIOGRAMS -

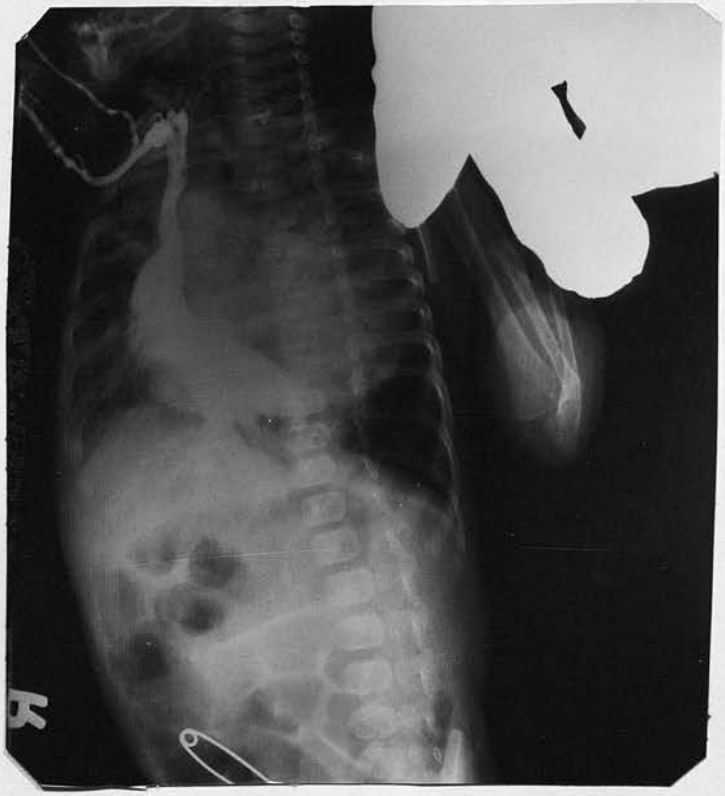


Fig 1. As the inner shadow of the right atrium is followed, the loss of continuity indicates the site of the atrial septal defect, and the medium is seen shunting to the left side.

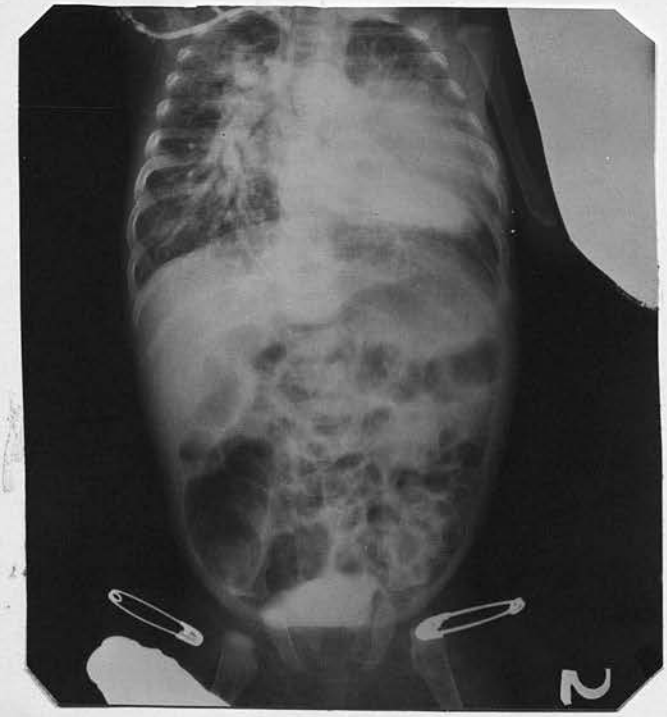


Fig 2. Infant aged six months. Note the huge pulmonary artery and great dilatation of its branches.

of the left heart and aorta. It is of course necessary to avoid mistaking the opacified right atrial appendage for medium "crossing the atrial septum" (see Dotter and Steinberg 1951).

Additional useful information was obtained concerning the size of the right atrium, pulmonary arteries and aorta. Where the latter was well visualized, it generally seemed of good size - though this is said by Abbott (1928) to be unusual in atrial septal defect.

In the older children, the examination was much less reliable in localizing the site of defect, though an intracardiac shunt was presumptively present.

In both groups however, the diagnosis was checked upon in several cases by cardiac catheterization. A further useful point is that, in infants, an atypical patent ductus arteriosus simulating atrial septal defect may be excluded by absence of re-opacification of the pulmonary artery from the aorta, this will be illustrated later in the section upon patency of the ductus arteriosus. Illustrative films of the results of angiocardiography in atrial septal defect are reproduced.

The electrocardiogram in atrial septal defect

The value of this investigation has progressed with the years. Thus Roesler (1934) noted right axis deviation in larger number of his cases where the electrocardiograms were available. By 1940 Routier et al. had described right bundle branch block (R.B.B.Bl.) in the majority of 23 cases of atrial septal defect. Bedford, Papp and Parkinson (1941) noted a high incidence of arrhythmias, large 'P' waves, and prolonged P-R interval. Taussig (1947) considers that large 'P' waves, a long P-R interval, and splintered QRS to be usual.

A detailed study (principally of adults) by Barber, Magidson and Wood (1950) suggested that conspicuous 'P' waves are not a feature in atrial septal defect, and that the P-R interval was commonly at

TABLE 9

ELECTROCARDIOGRAMS

Case	Age	'P' Waves	Axis	Condition	Strain Pattern (Right Heart)
200	7/12		R	Inc. RBBB	Yes
173	2/12				
157	1/12				
149	13/12		R	Inc. RBBB	
146	5/12		R		Yes
145	3/12				
91	6/12				
103	3/12	Peaked in II	R		
74	3/12		R		
32	3 yr		R		Yes
25	6/12		R		
24	13/12		R		Yes
16	3/12				
14	3/12	Tall in II	R		
8	4/12		R		
12	13/12				
13	6/12		R		
17	18/12	Peaked in II	L	Inc. RBBB	Yes
46	1 yr				
50	2 yrs				
75	3/12		R		
104	13/12	Peaked in I & II	R		
110	18/12	Peaked in II & III	R		Yes
134	3/12		R		
141	3/12				
235	3/12		R		Yes
23	6/12				
197	8 yrs	Peaked in II	R		
77	2 yrs		L		
89	7 yrs				
156	11 yrs		R	Inc. RBBB	
92	9 yrs		R		Yes
5	6 yrs	Peaked in II	R	Inc. RBBB	
81	10 yrs		R		Yes
86	6 yrs		R		Yes
56	8 yrs		R		Yes
199	9 yrs				
180	11 yrs	Peaked in II	L	Inc. RBBB	Yes
94	5 yrs		R		Yes
107	10 yrs		R		Yes
117	10 yrs		R	Inc. RBBB	Yes

RBBB = right bundle branch block
R = right
L = left

the upper range of normal. The axis was to the right in some 50% of the series, left axis deviation was associated with bundle branch block. This, (complete or incomplete), occurred in some 95% of the cases. Strain pattern of the right heart was rare, as was arrhythmia (this latter was found in the older age group only).

Smull and Lamb (1952) in their review of the electrocardiogram findings in a paediatric series of atrial septal defect found right axis deviation in two-thirds, evidence of right ventricular hypertrophy in all, prolonged P-R interval in the majority, and right bundle branch block once.

In this series, standard lead electrocardiograms were recorded in all patients, the majority had augmented unipolar limb and praecordial leads also.

The results are recorded in the table (9) and should be considered in relation to the child's age. The reason for this is discussed in the section on tetralogy of Fallot where a similar interpretative problem arises.

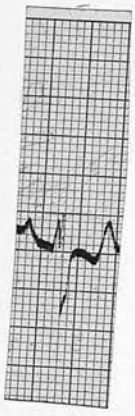
In the infant group it will be seen that the 'P' waves although 'peaked' in some instances, were abnormally tall in only one (case 14) when compared with the standard of Ashman (1938).

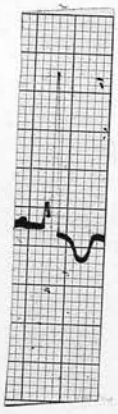
The axis was to the right in most cases in this group in keeping with the findings of Smull and Lamb in their series, but also compatible with normality as defined by Ziegler (1951). Two cases showed left axis deviation which was associated with right bundle branch block.

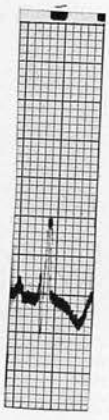
The problem of a 'strain' pattern in children of this age is of great complexity. Smull and Lamb (1952) claim this as constant, their criteria being the appearance of delay in the intrinsicoid deflection over the right ventricle, and the appearance of right axis deviation. Both of these occur in the normal infant - which they admit, and therefore the appearance of a 'strain' pattern, as evidenced in their series by delay in the intrinsicoid deflection,

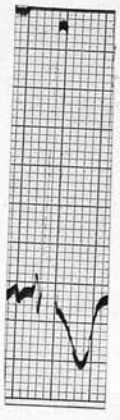
ATRIAL SEPTAL DEFECT

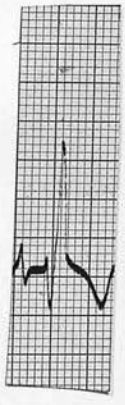
5 CASES - LEAD V_1











Each shows evidence of right bundle branch block.

change in the RS-T segment and shift of the transition zone to V_5 or V_6 is not thought to be significant. The phenomenon of interventricular block, partial or complete, may be diagnosed with more confidence as an abnormality, and has therefore much more significance. Four such cases were seen in the younger group, the earliest was aged 13 months. It is of interest that case 50 showed an essentially normal electrocardiogram at the age of 18 months and two years, but had developed a right bundle branch block by the age of $2\frac{1}{2}$ years. This would suggest that the conduction defect is secondary to the change in the right ventricle, and not a part of the congenital lesion as Dry (1948) suggested, though his claim is negated by Routier (1940) and Barber, Magidson and Wood (1950).

Earlier writers (Taussig 1947, Bedford, Parkinson and Papp 1941), have noted a prolonged P-R interval in cases of atrial septal defect. In this series, even allowing for the shortening of the P-R interval which is usual in young children and infants; this was seen only twice. An arrhythmia (premature ventricular contractions) was seen once only in the infant group.

In the thirteen older children studied, the ' P' waves were again never pathologically increased in size. The axis was to the right in all cases except 3. In one there was a balanced tracing; in two others with right bundle branch block, the axis was to the left. One third showed right bundle branch block (usually in those aged nine or more), one case showed supra-ventricular tachycardia, five showed evidence of a right ventricular strain pattern, and this is probably significant in these older children, since the occurrence of physiological right ventricular dominance is so much less than in infants and younger children. There was no case of atrio-ventricular block.

Summary

In all the cases of this series, the patterns were essentially

those reported by Bedford, Magidson and Wood (1950). Changes in the 'P' waves were rare, as was A-V block. Right bundle branch block occurs as early as one year, and the incidence appears to increase with advance of age. Strain patterns are difficult to evaluate in young children, but occur in the older age group with some frequency. The axis is generally to the right. Some representative tracings are presented in the appendix.

Physiological investigations in atrial septal defect

Cardiac catheterization by the technique of Cournand and Ranges (1941) is of great value in the diagnosis and investigation of this lesion. It was applied by Brannon, Weens and Warren to this end in 1945 and enlarged upon by Howarth et al (1947) and others.

In most cases the diagnosis may be strongly suspected by the presence of a significantly higher blood-oxygen level in the right atrium as compared with samples from the venae cavae. Otherwise the lesion may be anatomically demonstrated by the passage of the catheter across the septal defect into the left atrium. This may be confirmed by drawing a blood-specimen of high oxygen content from this site, and also by passage of the catheter into a pulmonary vein.

Where the catheter is not passed through the septal defect, the high oxygen level in the right atrium may be due to the emptying of an anomalous pulmonary vein, which indeed may be catheterized. Drainage may occur directly into the right atrium, the venae cavae, or the coronary sinus, as described by Smith (1951). If there are other features typical of a left to right shunt (enlarged heart, hypervascular lung-fields, and a typical history), this possibility may be ignored in making the diagnosis. However, as has been pointed out by Swan (1953), the coexistence of atrial septal defect with anomalous pulmonary venous drainage is common enough. This will therefore upset any calculation of the haemodynamics in these cases.

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On anatomical grounds, the propinquity to the septum of the point of emptying of these veins whether normal or abnormal, renders the recognition of their exact course to the left or right atrium a matter of considerable difficulty. Swan et alii (1953) have shown the possibilities of the use of Evans blue dye estimation after differential chamber injection; this method would be useful in such cases.

Again it is theoretically possible for the tip of the catheter to open a functionally closed foramen ovale. Here again, the presence of supporting clinical data such as pulmonary hypervascularity will be of great significance.

Cardiac catheterization was carried out in cases 104, 180, 199, 56, 92, 156, 89, 17, 5, 50, 77 and 236. The information obtained enabled calculation of the cardiac output, degree of shunts, and pressure relationships to be made. A large left to right shunt was usual, being eleven litres in case 156. Generally this is associated with a fall in pulmonary arteriolar resistance (31.9 dynes cm.$^{-5}$ in the case quoted), the pressure in the right ventricle and pulmonary arteries being normal. Certain cases however (199, 92), show a raised pressure in the right ventricle (in case 199 - 200/-13), with a rise in pulmonary resistance. Calculation revealed small net shunts in these cases, or minimal reversal of the shunt. No case with a large right to left shunt was seen in this paediatric series, but it has been seen in adults, and has been often reported by others.

It is difficult to correlate the degree of shunting with definite clinical phenomena. Since these children were in the low growth percentiles, a superficial association between this and the degree of shunt was noticed; in the absence of reliable data concerning the cardiac output of normal children, as measured by Fick principle, it is equally impossible to test this hypothesis.

Complications

Many of these, such as respiratory infection and laryngeal palsy have been mentioned incidentally. Congestive cardiac failure occurred

TABLE 10

DEATHS

Case	Age at Death	Post-Mortem	Cause
200	9/12	No	"Died suddenly"
74	9/12	No	"Died suddenly during mild resp. infection.
46	1 yr	No	Angiocardiogram
110	$2\frac{1}{2}$ yrs	Yes	Congenstive cardiac failure
141	6/12	Yes	Pneumonia
235	4/12	Yes	C.C.F.
107	$10\frac{1}{2}$ yrs	No	C.C.F.
94	5 yrs	No	C.C.F.

Total infant = 6
Total older = 2

8

in three cases (94, 110, and 235). The condition was temporarily relieved by digitalis and mercurials, but death occurred without the child being completely free of signs. Bacterial endocarditis, though occasionally suspected was never proven by blood-culture during life; this is in keeping with the opinion of Barber, Magidson, and Wood (1950) who consider that patients with atrial septal defect are virtually immune. In case 110, examination of the brain at post-mortem revealed an early abscess in the occipital lobe which grew B. Coli. This was unsuspected during life in spite of routine fundoscopy at regular intervals.

There were eight deaths in the group of 42 cases, most of them in the first year of life. Many of the others being followed are in a parlous condition, and the impression is that this condition is a severe one in both morbidity and mortality. Few of these children had an adequate exercise tolerance, many were quite severely disabled.

It would seem from a review of the published adult cases that the prognosis of isolated atrial septal defect is relatively good. This is due to an unwonted selection of cases, in so far as many of the severe cases described here, or in the series by Smull and Lamb (1952) would be the nature of things, be excluded. Even the prognosis of Taussig (1947) seems to be somewhat optimistic.

Treatment

This divides itself naturally into general and specific. The former will be considered first, and is 'secundum artem'. The principal problems of early infancy are: parental fear, baby's irritability, feeding difficulty with failure to gain weight, and respiratory infection.

Much explanation and encouragement is necessary, since a diagnosis of heart-disease carried the echo of a death knell to many parents. It may be said with some confidence that the child with septal defect tends to improve with ageing. Taussig (1947) similarly states that after a stormy infancy, the child may do quite well. It is most

important to give parents this word of comfort, which is much appreciated by them. A simple explanation of the cyanosis on crying, and assurance that it is not necessarily harmful is of great benefit.

The infant's irritability, often associated with respiratory infection, or manifested by crying and pushing away of the bottle, is a common complaint. It may be greatly relieved by the judicious use of phenobarbital or chloral hydrate; a nocturnal dose is especially useful in assuring a few hours sleep for the parents.

Failure to thrive, manifested by poor and irregular feeding and minimal weight gain is difficult to handle. There is no specific except patience and effort by the mother; she should not expect a normal weight increase, and must be warned accordingly. There is no place for the daily weighing of these babies; this only brings about a lowering of the parental morale.

Respiratory infections are exceedingly troublesome, but fortunately respond to simple treatment. An electric vaporizer (though a kettle will do) is most useful, especially for mild attacks. Antibiotics should be freely used in the presence of fever, or where the infection appears to involve the lower respiratory tract. There does not appear to be any clinical evidence that antibiotics lose their efficacy by frequent use.

Prophylaxis is exceedingly difficult; protection against pertussis which seems to be particularly distressing in these children should be begun at two or three months of age. In the more general sense, a few cases studied here appear to have benefited from the use of a slow-acting penicillin derivative (Bicillin). This may be given at intervals of 2 weeks to one month and is safe and relatively cheap. While the epidemiological problems preclude accurate assessment of the efficacy of this measure, it is well worth a trial.

Specific treatment

This is of course closure of the defect by surgical means, and

is at present practiced in only a few centres. The presence of an associated defect (e.g. ventricular septal defect) should be excluded by preliminary cardiac catheterization. The use of hypothermia (Bigelow 1950) with or without artificial extra-corporeal circulation seems to be an almost essential adjunct. Bailey (1953) has described a method whereby the septum may be closed blindly without opening the atrium. It is not proposed to deal further with surgical treatment, though it should be noted that cases with advanced pulmonary vascular changes would not appear to be suitable cases.

The responsibility of the clinician lies in the early recognition of these cases, and insistence upon their full investigation. The clinical features which are of note are fully described in this section, together with an attempted evaluation of the methods of investigation.

Many symptoms are common to cyanotic and acyanotic heart disease, and the difficulty of exact diagnosis may be great in the young infant where cyanosis is easily provoked in the 'shunt' group. Many cases of patent ductus, atrial septal defect, and some of ventricular defect will have a similar clinical history and physical signs. The x-ray may show little except pulmonary hypervascularity, and right ventricular enlargement. In infancy the electrocardiogram is essentially useless for definitive diagnosis. Cardiac catheterization, provided the septal defect is crossed is very reliable.

Review of the physical signs in the present cases suggest that in infancy murmurs are quite non-specific. In the older group diastolic murmurs are common and do not signify mitral stenosis even if apical. The high incidence of vocal palsy is noted, and seems to bear a close relationship to atrial septal defect. The may be transient, but should be asked for specifically if not volunteered.

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Section 8

VENTRICULAR SEPTAL DEFECT

ISOLATED VENTRICULAR SEPTAL DEFECT

This syndrome, eponymously the 'Maladie De Roger ' is reckoned to be among the commoner acyanotic congenital defects of the heart (Brown 1950). Roger (1879) described three cases with a systolic murmur, no cyanosis, and good health "except for a tendency to pulmonary catarrh". These three cases were unsupported by autopsy, though he did in the same year describe a single case with autopsy control. Since that time many cases have been described (Laubry and Pezzi 1923, Perry 1931). The mortality in the described series is low so that post mortem confirmation is wanting in most cases. This is a point of some importance since Wood (1950) found that some cases diagnosed as ventricular septal defect actually had innocent parasternal murmurs.

Pathogenesis

Keith (1909) was of the opinion that defects of the septum anterior to its membranous part were due to a primary growth arrest. The frequency with which this type of septal defect is associated with pulmonary arterial lesions suggests that a lesion of the bulbus cordis may occur. A few cases may be acquired (Brown 1950). Rubella during early pregnancy has been implicated (Swan et al 1944).

Anatomy

The defect is generally high and placed near the base of the septum in close relationship to the septal cusp of the tricuspid valve. It is of variable size, but generally 0.3-1 cm. in diameter (Taussig 1947).

Occasional cases are reported where the defect is near the apex. A typical case is figured by Dry et al. (1948).

Clinical features

There is a considerable confusion in this regard. Roger (1879), included in his criteria: good general health, absence of cyanosis, a harsh systolic murmur maximal between the nipple and the sternum

TABLE 1

AGE - SEX DISTRIBUTION

	Male	Female
0 - 6 mths	1	2
7 - 12 mths	3	1
13 mths - 2 yrs	2	2
3 - 5 years	4	1
6 - 8 years	2	1
9 - 11 years	1	1
Total = 21 cases.	13 = 62%	8 = 38%

with a coincidental thrill. Transmission into the great vessels was not noted. A tendency to 'pulmonary catarrh' is recognized.

Brown (1939) states that the condition (Maladie de Roger) is characterized by an "absence of symptoms with marked physical signs". Taussig (1947) agrees essentially, but differentiates "high" ventricular septal defect in which the blood is "shunted into the pulmonary artery". She states that this latter type may occasionally show cyanosis or slight clubbing. The validity of this opinion is doubtful.

Wood (1950) states that the majority of his cases (24) were symptom free, though 5 led a restricted life and one had congestive cardiac failure. Marquis (1950) describes four cases in children, two proven by post-mortem. All of these were severely affected, had frequent respiratory infections and were underweight. Congestive cardiac failure also occurred.

If all observers are correct then, a synthesis of opinion suggests that most cases are asymptomatic, occasional cases will be severely affected, and some will die of congestive cardiac failure. Most authorities describe the same physical signs, the details of which will be considered below.

The problem of diagnosis is squarely put by Wood (1950) who observed a high observer error in the pre-catheterization diagnosis.

Material

Twenty-one cases are presented. The age-sex distribution is given in table 1. The principal complaints are presented in table 2. Poor weight gain and "murmur" head the list. This latter was so prominent in three cases that the mother was able to give a graphic description of the characteristics and localization of the thrill! All of the symptoms elicited are given in table 3. It is seen that the usual complaints are:- Dyspnoea, usually of moderate degree but sufficiently obvious to make the mother aware of it, and consisting essentially in low exercise tolerance. Dyspnoea at rest

TABLE 2

Presenting complaints	No.	Percentage
Poor Weight Gain	8	38
"Murmur"	5	24
Respiratory Infections	2	10
Associated Infections (one Bact. Endocarditis one osteomyelitis)	2	10
Associated Defects (one cleft-palate, one tracheo-oesoph. fistula)	2	10
Enlarged Liver	1	4
Haemoptysis	1	4

is rare. Poor weight gain is also commonly present. Frequent upper respiratory infections are noticeable. Easy fatiguability is probably the commonest single feature.

Associated congenital defects were unusual and coincident severe infections occurred twice only. One child proved to have Bantis syndrome to explain the enlarged liver. The less common features may be obtained from the table. Cyanosis on exercise occurred twice, in one it was confirmed by personal observation, and the diagnosis was proven at cardiac catheterization. In the other the 'cyanosis' was peripheral in type, apparently being provoked by exposure to cold. Only two children were asymptomatic.

It is of course dangerous to generalize on the basis of this short series. Some selection must occur in any hospital series, and therefore the series of Perry (1931) based on the examination of school children is perhaps more representative. However as already mentioned, the absolute diagnosis of this flaw is difficult by purely auscultatory methods such as he employed.

In any event, it is obvious that many children referred to hospital are far from being symptom-free. The history of those children here described broadly resembles that of other intra-cardiac shunts (vide supra) though the over-all incidence and severity of the symptoms is less. An attempt will now be made to trace the natural history of the condition (see table of symptoms).

At birth these children are essentially normal, without the history of transient cyanosis which is common in atrial septal defect. At the 'six-week' examination the murmur may be heard.

During the first year poor weight gain is common, sometimes this is associated with irritability or refusal of food (25%). Frequent respiratory infection - usually colds, otitis media and 'bronchitis' occur in a large percentage in the first year. In a few, there will be intercurrent broncho-pneumonia. The milestones of development

TABLE 3

ALL SYMPTOMS

	No.	% of all cases
Poor Weight Gain	13	62
Frequent Respiratory Infections	13 (3 severe)	62
Dyspnoea on Exercise	14 (5 slight)	66
Easy Fatiguability	15	71
Murmur	9	43
Irritability in Infancy	5	24
Cyanosis on Exercise	2	10
Associated Defects	2	10
Associated Infection	2	10
Epistaxis	1	4
Haemoptysis	1	4
Mental Retardation	2	10
Enlarged Liver	1	4

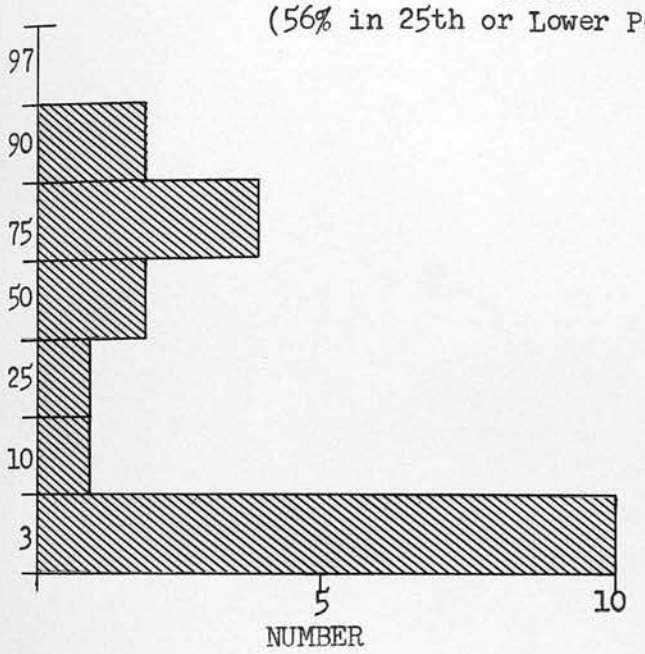
TABLE 4

HEIGHT AND WEIGHT

DISTRIBUTION

HEIGHT	PERCENTILE	3	10	25	50	75	90	97
(18 CASES)	NUMBER	10	1	1	2	4	2	-
WEIGHT	PERCENTILE	3	10	25	50	75	90	97
(20 CASES)		10	2	2	4	2	-	-

HEIGHT
(56% in 25th or Lower Percentile)



WEIGHT - 20 CASES
(73% in 25th or Lower Percentile)

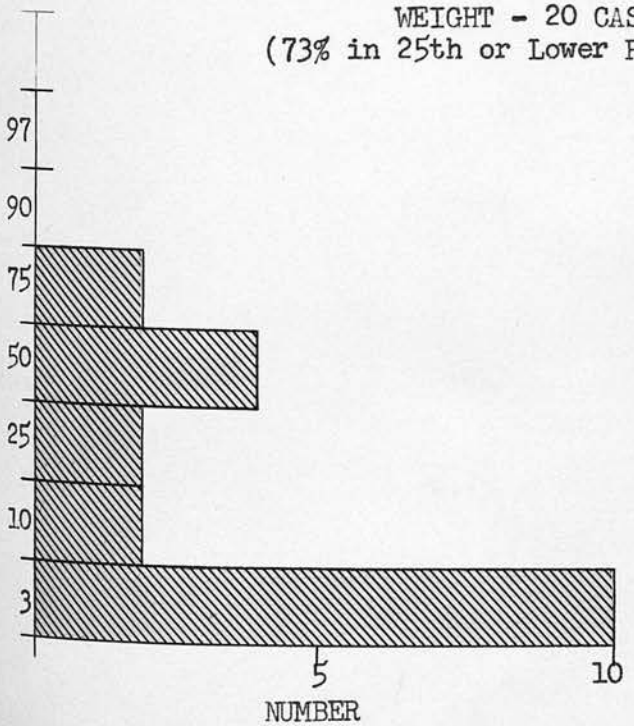


TABLE 5

SIGNS

	No.	
Chest Deformity	9	
Significant Anaemia	10	(2 associated infections
Apex Normal in Type	11	
Apex L.V. in Type	5	
Apex R.V. in Type	4	
Clinical Cardiac Enlargement	7	
Systolic Thrill	20	
Systolic Murmur	20	
Diastolic (Apical) Murmur	5	
"Normal" Splitting 2nd Pulmonary Sound	12	
Wide Splitting 2nd Pulmonary Sound	6	
No Splitting 2nd Pulmonary Sound	3	
Triple Rhythm	5	

already presented. An example of such a deformity in case 165 (where the diagnosis was proven by cardiac catheterization) is reproduced in plate . Essentially similar findings were reported by Marquis (1950) in his short series.

Mental development

Two children were mentally retarded. Neither was a Mongol.

The cardiovascular system

The apex beat

Roger's classical description of the condition has already been considered. He also noted that the "total mass of the heart had a strong impulse without any appreciable impact at the apex". It is difficult to elucidate exactly what is meant, but possibly the latter statement may be construed that a "tapping" apical beat was not present.

A more recent authority (Wood 1950) states that the apex beat in this syndrome is generally "heaving" or left ventricular in type. This is of course generally normal (Barber, Magidson and Wood 1950) but is exaggerated in conditions causing left ventricular hypertrophy, e.g. Hypertension, or some cases of ventricular septal defect. In this series, an effort was made to assess this sign and the results are recorded in table 5. In the majority (11), the apex was reckoned to be normal. Four cases had a "left ventricular" apex, and a similar number a "right ventricular type". This latter might be considered an unusual phenomenon in this condition, though, as seen under "haemodynamics", right ventricular hypertrophy will arise in a proportion of cases.

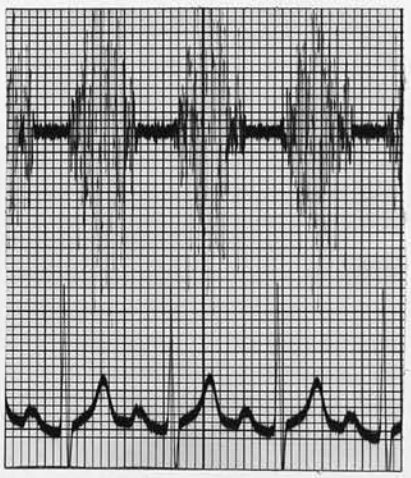
The thrill

Roger placed this 'between the nipple and the sternum,' that is approximately in the 4th left interspace. Other authorities (Brown 1950, Wood 1950) confirm Roger's opinion, and Wood states that a thrill is an essential point in the diagnosis of ventricular septal defect. Table 5 shows that a systolic thrill was present in all but one case - a ten day old infant in whom the diagnosis was confirmed

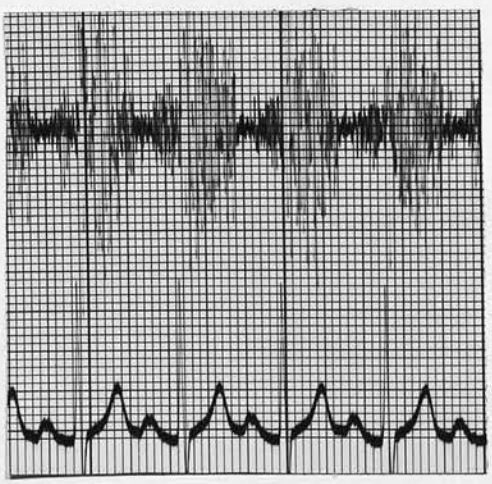
VENTRICULAR SEPTAL DEFECT

PHONOCARDIOGRAMS

1. Log. Recording taken in 4th left interspace near the sternum. This shows a loud systolic (Roger's) murmur.



2. Log. Recording at apex. A loud systolic murmur is obvious. A diastolic is also seen.



at autopsy.

Cardiac enlargement sufficient to be clinically assessable, was present in six of the twenty cases.

The murmur

Reference has already been made to Roger's original findings; little has been added to his description (Brown 1950). Table 5 shows that these were the general findings in this series. However in 3 cases (18, 208, 27), the point of maximal audibility was in the higher interspaces. These cases were variously proven by cardiac catheterization or autopsy. It is evident that diagnosis by localization of the murmur will break down in some cases, especially infants, since the signs will simulate those present in atrial septal defect or some cases of patency of the ductus arteriosus (see appropriate sections of this thesis).

In general however the murmur is maximal in the lower interspaces and this is the most valuable point. There was no evidence that the murmur of ventricular septal defect was louder than that in other types of shunt; similarly its transmission is not of consequence in differential diagnosis.

Infundibular pulmonary stenosis may present with a loud bruit in the lower left interspaces (Abrahams and Wood 1951), in this circumstance attention to the quality of the second pulmonary sound is of value in older children.

Diastolic murmurs

Wood (1950) notes the presence of apical diastolic bruit in 50% of his cases of ventricular septal defect; the sign was most common in his severe cases. Selzer (1949) also discusses the occurrence of such a murmur. Nadas and Alimurung (1952) describe five such cases.

Excluding the two children who died before 2 months of age, five of the eighteen cases considered here had apical mid-diastolic murmurs (see phonocardiogram diagram). Three of the cases were

proven by catheterization, the fourth at autopsy. In this last child no evidence of mitral disease was found.

Wood (1950) and Nadas and Alimurung (1952) consider this murmur to be due to the increased flow through the mitral valve into the left ventricle (which may be enlarged). This may lead to "functional stenosis of the mitral valve." It is of some confirmatory value that the present cases with diastolic murmurs were among those most severely affected. The appearance of left auricular and ventricular enlargement in three cases, and of combined ventricular increase in the other two also tends to confirm that the murmur is related to left sided cardiac enlargement.

The second pulmonary sound

In normal children the second pulmonary sound has two distinct elements - aortic and pulmonic: this has been confirmed by phonocardiogram (Leatham 1951), and a clinical subdivision has been made by Barber, Magidson and Wood (1950). Personal examination of a control series has shown that these criteria hold except for young infants of less than nine months or so.

The table (5) describes the findings in this series; normal splitting of the second sound is usual, except in infancy. Six of the cases showed a widely split pulmonary sound. In two an associated right bundle branch block was found.

While a widely split second sound does not occur as often as in atrial septal defect is a useful point in the differential diagnosis from infundibular pulmonary stenosis.. This does not however apply to infants of less than ninemonths; a case has been seen of an infant aged eight months who had a loud low systolic murmur and thrill with absent pulmonary second sound (confirmed by phonocardiography), in whom a clinical diagnosis of pulmonary stenosis was disproven by cardiac catheterization. A ventricular septal defect was demonstrated.

Anaemia

Some 50% of the cases were found to have significant anaemia (less

TABLE 6

RADIOLOGICAL FINDINGS

Cardiac Enlargement (A.P. View)	12	(3 slight, 8 moderate, 1 marked)
Chamber Enlargement		
Left Ventricle	4	
Left and Right Ventricle	4	
Right Ventricle Only	6	(2 minimal)
Left Atrium	4	
Increase in Pulmonary Arterial Segment	12	(3 slight)
Increase in Pulmonary Vascularity	16	
Hilar Dance	1	
Angiocardiograms (see text)	6	

than 11 grams %); this responded readily to iron medication.

Radiology

Brown (1951) states that generally there is no change in the size and shape of the heart; rarely there may be slight general enlargement with some dilatation of the pulmonary artery.

MARQUIS (1950) in describing four severely affected cases states that both ventricle and the pulmonary artery were enlarged; Wood (1950) considers that in some cases the appearance may be indistinguishable from those in patent ductus arteriosus; his severe cases showed left ventricular enlargement and pulmonary plethora.

The relevant findings are presented in table 6. Thirteen of the 20 cases x-rayed showed some cardiac enlargement. Four cases showed evidence of enlargement of both ventricles, and the same number had left atrial enlargement. Right ventricular enlargement occurred in six cases, and left ventricular enlargement alone in three cases. Increase in the pulmonary vascularity and pulmonary arc were more common appearances. Hilar dance was present only once.

Of the cases showing right ventricular enlargement only, the diagnosis was confirmed at autopsy in one (140) and by catheterization in three (221B, 165, 27). Similarly cases 208, and 54 - showing combined enlargement were proven at autopsy and by cardiac catheterization respectively.

It is then possible to state from these findings that most of the observations of other authors have occurred in this series. It is however impossible to make out a definite x-ray pattern which will abruptly distinguish all ventricular septal defects from other forms of intra-cardiac shunt. Radiology is of value in distinguishing loud but 'innocent' murmurs from organic defect by the frequency with which bulging of the pulmonary arc and hypervascularity of the lung fields occurs. The combinations of chamber enlargement here recorded were seen in many other types of left to right shunt (e.g. left atrial and ventricular enlargement in patent ductus).

TABLE 7

ELECTROCARDIOGRAMS (18 Cases).

Normal	1
Right axis	9
Left axis	3
Neutral axis	1
Incomplete Right Bundle Branch Block	3
Incomplete Auriculo-Ventricular Block	1
Right Heart Strain Pattern	1
Left Heart Strain Pattern	1

The electrocardiogram

Brown (1950) with his unrivalled experience states that electrocardiogram changes are unusual. Taussig (1947) apparently feels that there is no specific appearance. Marquis in his survey of four severe cases notes that left axis deviation was usual, and that evidence of right and left ventricular hypertrophy might be present in the augmented limb and unipolar chest leads. The work of Ziegler (1952) however throws some doubt on the applicability of adult criteria to infantile electrocardiograms.

Wood (1950) found the electrocardiogram to be normal in his mild cases. "P" wave changes were not found. A tall "R" wave with inverted "T" wave occurred over the left ventricular surface leads in some of his patients. Three had a definite right bundle branch block pattern.

The table (7) suggests that in the majority of cases (13) the electrocardiogram was normal, though nine showed right axis deviation, and three left axis deviation. In two of the last, this phenomenon could be reversed by deep breathing. A definite right heart strain pattern was seen in two cases and left ventricular preponderance once. Affection of both ventricles is suggested in one other case.

Incomplete right bundle branch block occurred in three cases and incomplete a-v block in one.

As with radiology there is no pattern which does not occur in other conditions. The similarity of the findings to those in patent ductus arteriosus is quite striking.

Certain E.C.G.'s are reproduced to illustrate the variations found.

Complications

These were relatively few. One case (195) had subacute bacterial endocarditis proven by blood culture. Another (case 98) presented with acute femoral osteomyelitis with a staphylococcal bacteraemia. Gelfman and Levine (1942) noted infection as the cause of death in 8 of their 14 cases, the majority being over two years of age. The low incidence here is in keeping with Marquis's (1950) opinion that

Catheter Position	Pressure mm. Hg.	Volumes % Oxygen	
SVC	M = 1.5	12.3	
IVC	M = 1.5	8.8	11.0
RA	3/1 M=1	11.4, 11.6	
RV (LOW)	75/0	14.1	
RV (HIGH)	65/0	13.7	
LPA	73/48 M=58	13.7	
LPA (WEDGE)	M = 14		13.2
RPA	75/60 M=69	12.6	
RPA (WEDGE)	M= 14		
L. FEM. A.	75/53 M=60	15.5	
% SATURATION FEMORAL ARTERY		88.4%	
Oxygen Capacity		17.9	
Pulmonary Vein O_2 (Assumed 95%)		16.6	

Left ventricular work = 2.27 kg. M/min
Right ventricular work = 3.2 Kg. M/min.

This cardiac catheterization of a ventricular septal defect shows a 3 Vol. % increase from atrium to ventricle. There is pulmonary hypertension also, with increase in right ventricular work.

this is a rare complication in some series. The Tuberculin reaction was uniformly negative in all but one case (195). No positive Wasserman reaction was found.

The haemodynamics of ventricular septal defect

The relatively higher pressure in the left ventricle will cause a left to right shunt. The pulmonary flow will depend upon the pulmonary vascular resistance; if this is low or normal, the increased return to the left side of the heart will increase the work of the corresponding ventricle. An increase in right ventricular work will not occur if it is postulated that this chamber acts passively on the left to right shunt, being dynamically concerned only in the propulsion of the effective pulmonary flow. The presence of a shunt at the ventricular level will lead to increased work of the left ventricle if an adequate systemic flow is to be maintained.

Burchell et al. (1948) and Wood (1950) demonstrated that an increase in pulmonary artery pressure occurred in ventricular septal defect. Swan and his co-workers (1954) have amplified the concept. They show that ventricular septal defect is the commonest type of intracardiac shunt to show this complication. This results frequently in increased vascular resistance with consequent increase in right ventricular work.

It is then possible for a train of events to occur which will explain the findings of right, left, or combined ventricular hypertrophy evidenced by radiological or electrocardiographic findings. The picture will depend primarily on the level of pulmonary vascular resistance. This must operate at a level sufficient to prevent flooding of the lungs (Swan 1954), but low enough to allow an adequate systemic output. A marked increase in pulmonary resistance will lead to hypertrophy of the right heart, and eventually to reversal of the shunt. This is probably the course of events in Eisenmenger's complex, which argues the essential unity of this disease with 'ventricular septal defect or 'maladie de Roger'. Certainly the late onset of cyanosis in this condition (Taussig 1947) may be related to an increase in

pulmonary vascular resistance. The cause of this increase is still debatable. The work of Civin and Edwards (1950, 1951) suggests that persistence of pulmonary arterioles of a foetal type may provide one factor, their work specifically concerns Eisenmenger's complex. Degenerative changes in the lung vessels have also been adduced as a cause (Old and Russell 1950) though Welch and Kinney (1948) were unable to demonstrate a statistical difference between this finding in cases with septal defect and a control group. Vasospasm may be considered, and there is some evidence that the pulmonary pressure may fall after closure of atrial septal defect (Swan 1953); as the pulmonary flow will also decrease it is conceivable that a fall in resistance may occur in some cases. The findings of thrombi in the vessels of patients with patent ductus arteriosus and pulmonary hypertension (Hultgren et al 1953) may apply to cases of ventricular septal defect also. When the closure of ventricular septal defect become possible lung biopsy should shed some light on this particular problem.

Angiocardiography

Six patients were subjected to this method of investigation. The results in general were disappointing. It is obvious that it is impossible sufficiently to raise the pressure in the right ventricle to cause reversal of the shunt. Reliance then must be placed upon persistant filling of the right ventricle and enlarged pulmonary arteries during the time of left heart and aortic filling (Dotter and Steinberg 1951).

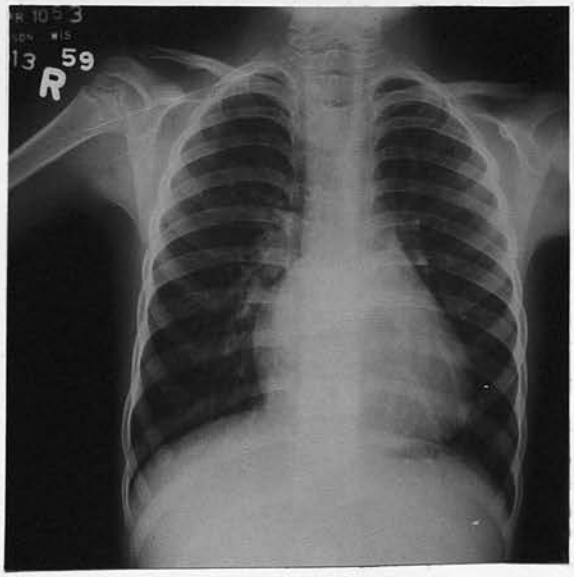
In three of the cases the angiocardiogram appeared to be normal, it was noteworthy that an apparently intact ventricular septum was well outlined in two. In another, the findings simulated an atrial septal defect; in the last, reopacification of the right ventricle contemporaneously with filling of the left ventricle was seen. In all however, useful information as to the size of the pulmonary vessels was obtained. In one case (not here described) the angiocardiogram was particularly misleading. This child had suffered from congenital heart disease with congestive failure on several occasions.

A loud low systolic murmur and apical diastolic suggested a ventricular septal defect. Cardiac catheterization showed right ventricular and pulmonary arterial hypertension but, due to reversal of the shunt, was not diagnostic. The angiocardiogram showed a huge left atrium. A diagnosis of mitral stenosis, probably due to fibro-elastosis was made. The angiocardiographic picture was in keeping with the criteria of Zinsser (1953). The mitral valve was explored because of the childs desperate condition. No stenosis was found. Autopsy revealed a typical high ventricular septal defect. It would appear that in ventricular septal defect the angiocardiogram is not only without positive value but may actually be misleading if undue emphasis is placed upon it.

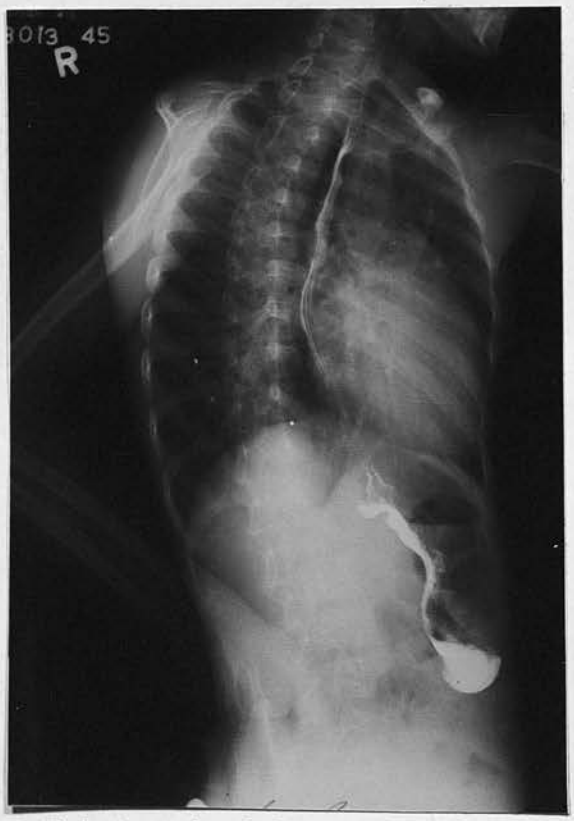
Summary

A series of cases of ventricular septal defect is presented. The morbidity is remarked. The signs, clinical, radiological and electrocardiographic are discussed. A review of the haemodynamics is offered.

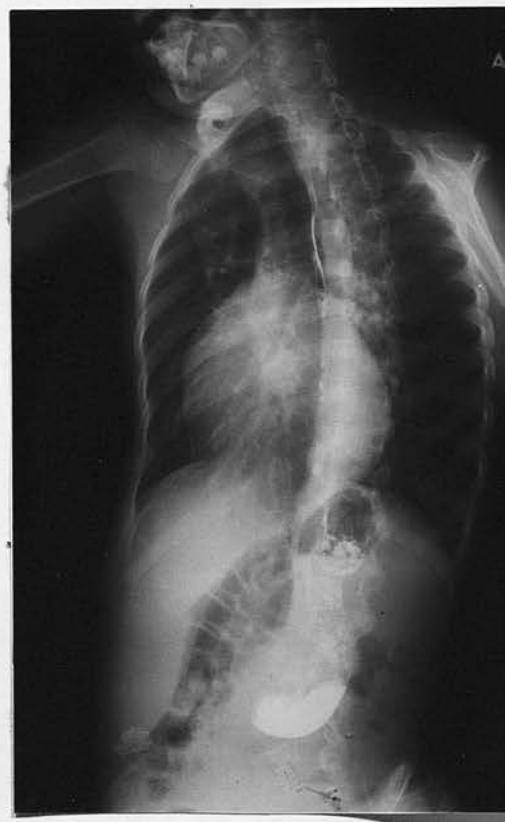
VENTRICULAR SEPTAL DEFECT (CASE 54)



A.P. View: Note prominence of pulmonary arc, increased heart size and hypervascularity of lungs.



R.A.O. Note fullness of pulmonary artery and right ventricle



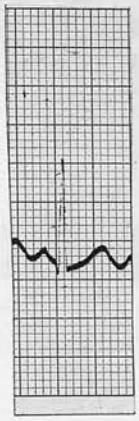
L.A.O. Note enlargement of left ventricle

VENTRICULAR SEPTAL DEFECT

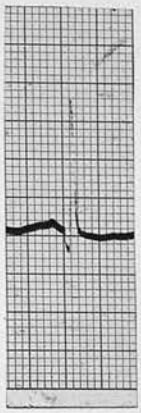
Note RR^1 pattern in V_1 indicating incomplete right bundle branch block.

1

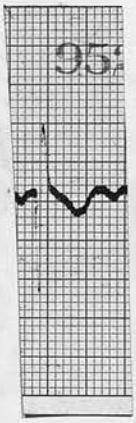
2



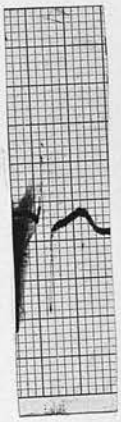
3



AVR

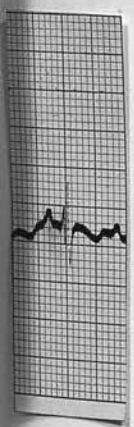


AVL

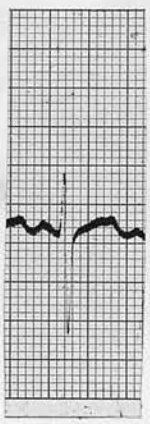


AVF

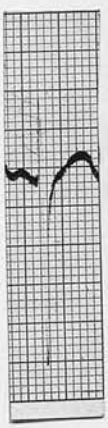
V_1



V_3

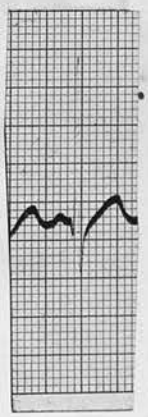


V_4

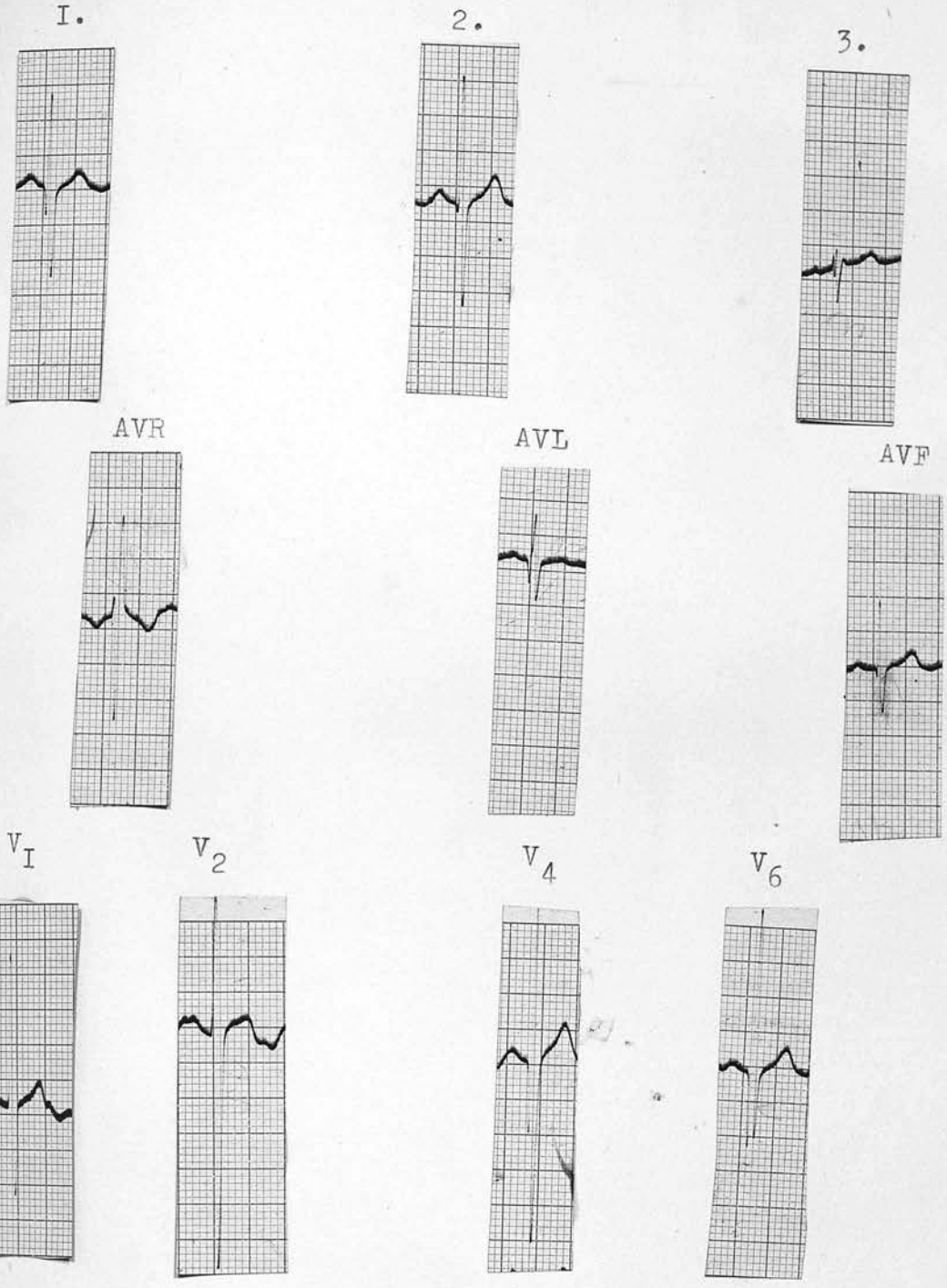


V_5

V_6

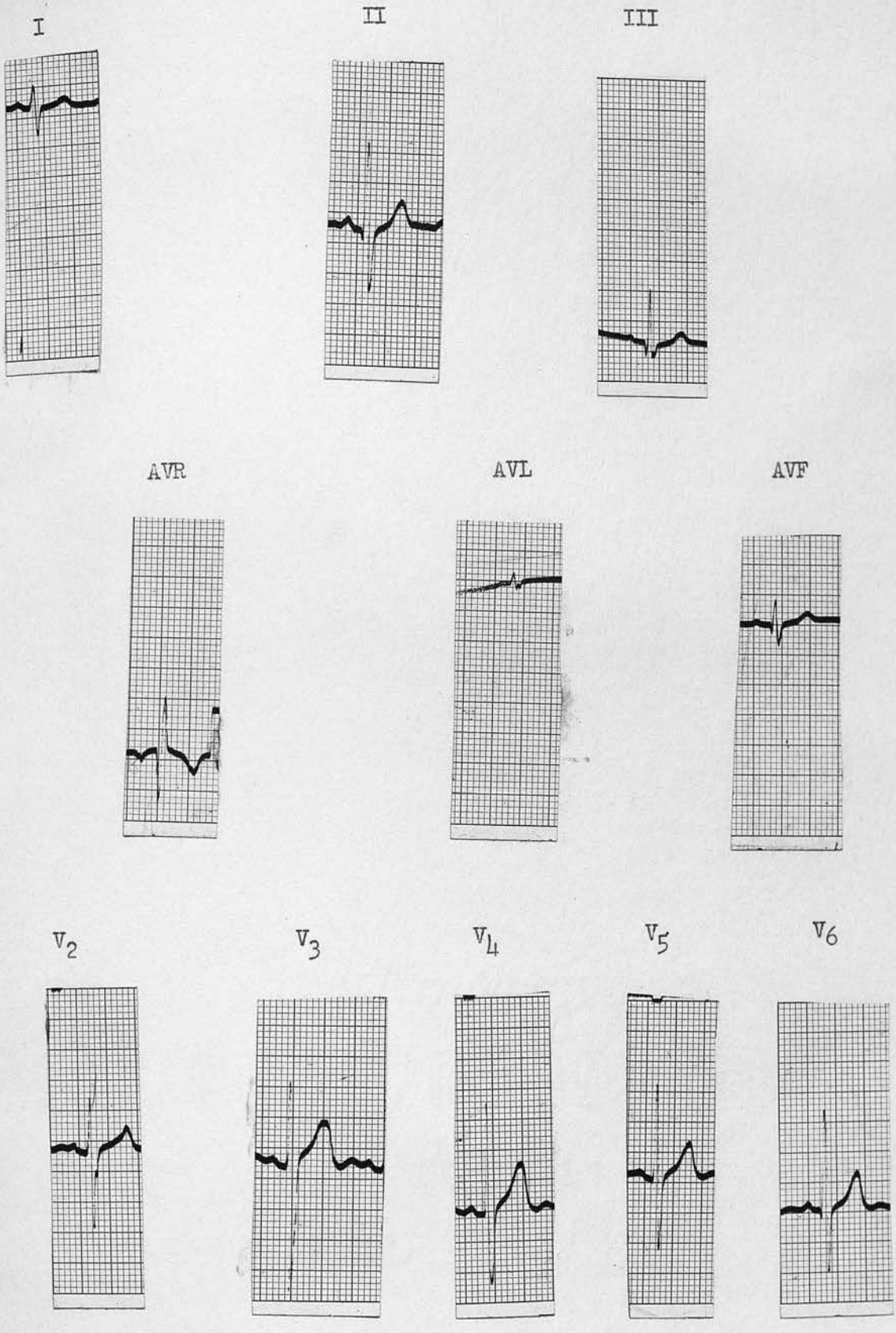


VENTRICULAR SEPTAL DEFECT
ELECTROCARDIOGRAM.



Note tall R waves in the right praecordial leads.A deep Q is seen over V_4 and V_6 .

ELECTROCARDIOGRAM - CASE 54



This electrocardiogram shows right ventricular dominance in the praecordial leads. The left ventricle was enlarged at fluoroscopy - see plate.

Weight chart during first year-- Ventricular Septal Defect.

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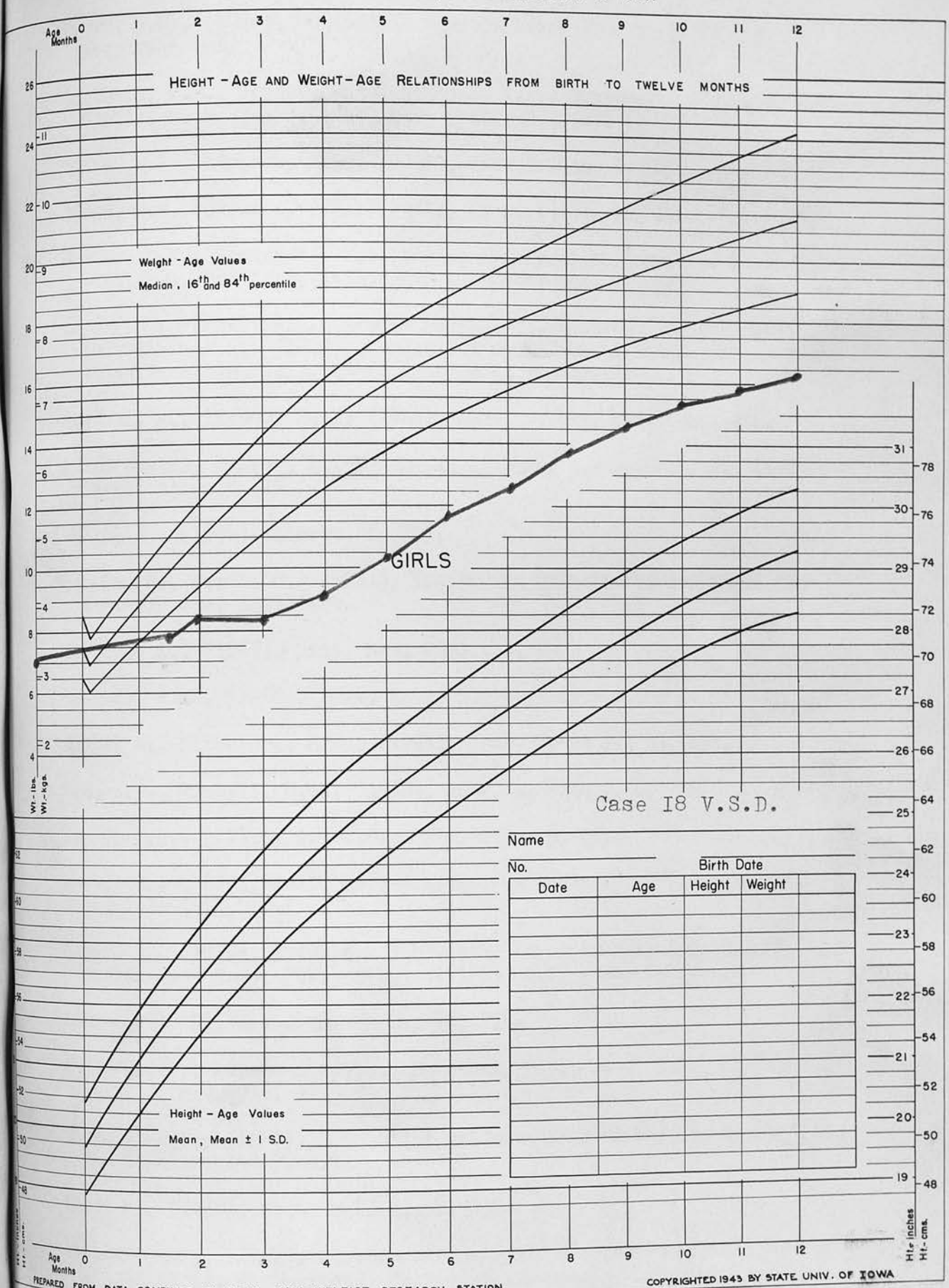

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Section 9

PATENT DUCTUS ARTERIOSUS

ISOLATED PATENCY OF THE DUCTUS ARTERIOSUS

Patency of the ductus arteriosus has been thoroughly described and investigated. It will therefore be dealt with shortly in this section.

Brown (1950), gives an excellent review of the historical aspects of this condition. The criterion for diagnosis for the past fifty years has been the continuous murmur described by Gibson (1900); except in infants this is the most accurate method of diagnosis.

Aetiology

The cause for persistent isolated patent ductus arteriosus remains as yet obscure. Cases have followed maternal rubella, (Swan et al. 1944). A familial incidence is noted by Brown (1950), and Ellis (1932). The former believes that some condition raising pulmonary vascular resistance may lead to persistent patency. In the same vein, Hultgren et al (1953), feel that some "foetal maladjustment" causes the equality of resistance in the systemic and pulmonary circulation to persist into post-natal life, thus militating against normal closure of the ductus.

Record and McKeown (1953) have pointed out that females with patent ductus tend to be born at certain periods of the year. The significance of this fact is obscure.

Pathology

The exact size of the ductus is variable; Gross (1952) describes vessels of up to 1.5 cm. in diameter. The present writer has seen three cases in young infants where the diameter of the ductus was equal to that of the arch of the aorta. The exact length is of less importance, the only point being that it be long enough for effective suture/ligation. The danger of the "window" type of ductus originally described by Gerhardt (1867) lies in the difficulty of surgical closure.

Degenerative changes may occur in the wall of the abnormal communication and lead to difficulties at the time of surgery (Brown 1950). Infective arteritis involving the pulmonary end of the ductus especially has been fully described by Abbott, (1951) and many others.

Secondary changes in the lungs are of great pathological and clinical interest. The association of marked pulmonary hypertension and patent ductus has been correlated with sclerotic changes in the pulmonary vessels by Hultgren and his associates (1953). These they consider to be due to multiple intravascular thrombi of which many subsequently recanalize. The parallel between these cases and certain patients with Tetralogy of Fallot in whom intravascular pulmonary thrombi are described (Rich 1948), is very striking, though of course the dynamics are quite different.

Physiology

During foetal life the ductus acts as a short-circuit from the pulmonary artery to the descending aorta. It does so in virtue of the high resistance of the pulmonary circuit at this time. With the expansion of the lungs after birth, the pulmonary vascular resistance falls greatly, and a pressure gradient will exist between the aorta and the pulmonary artery. Normally this will endure only until the ductus closes. If patency continues, a shunt between the two vessels comes into existence. The amount of the shunt will vary with the size of the communication and with the pressure difference between the aorta and the pulmonary artery. This latter will depend to some extent upon the pulmonary vascular resistance. In many cases the pulmonary arterial pressure is normal, (Bing 1951, Dexter 1947). Here a large left to right shunt at the aortic level will exist sometimes as much as 25 liters, (Hultgren et al). If a normal systemic output is maintained, this extra load greatly increases the left ventricular work.

When the pulmonary arterial pressure and pulmonary vascular resistance rise, there will be a decrease in the volume of the shunt: transient or permanent reversal may occur. In either situation the right ventricular work will increase with subsequent hypertrophy of that chamber.

TABLE 1

AGE - SEX DISTRIBUTION

Age	Male	Female
Birth - 6 months	3	1
7 - 12 months	1	1
13 - 24 months	2	2
2 - 3 years	-	2
4 - 6 years	4	5
7 - 9 years	-	2
10 - 12 years	2	2
	12 (45%)	15 (55%)

The values mentioned above may be measured at cardiac catheterization; if the aorta is entered by traversing the ductus, true estimations of the pressure gradient may be made. Alterations in the haemodynamics may be adduced by the clinical observation of cyanosis in the infant during crying or severe respiratory infection. Similarly the change of the murmur from "continuous" to systolic only during crying is presumptive evidence of increase in the pulmonary artery pressure. This latter phenomenon has been observed in several cases of this series.

Several factors then will enter the physiological field. The integrity of the left ventricle must be unimpaired to ensure an adequate systemic output in the face of a large and useless left to right shunt; the pulmonary vascular resistance must not be too great, altho' increasing this theoretically would help to reduce the shunt; undue increment will lead to an extra strain on the right ventricle or even reversal of the shunt.

Material

Twenty-seven cases are presented. These were all seen personally as inpatients or at follow-up. The table (1) gives the age and sex incidence. Some ten of the cases aged less than two years were of the greatest clinical interest. The diagnosis was generally made clinically, though angiocardiography and cardiac catheterization were resorted to on occasion. Surgical confirmation was obtained in all but four cases, and these seemed to be beyond clinical doubt.

Sex incidence

Females heavily load most series. Thus Brown (1950) reports almost three times as many females as males. Shapiro and Keys (1943) report similar findings. Record and McKeown (1953) summarize several papers to obtain the same result. In this series an almost equal sex incidence was present, reflecting the findings of Gilchrist (1945).

The anamnesis

Condition at birth:

This point was specifically investigated. All of these children

TABLE 2

PRESENTING COMPLAINTS (of 27 CASES).

	Number
Murmur	9
Dyspnoea	4
Poor Weight Gain	3
Failure to Thrive	3
Feeding Problem	2
Asthma	2
Frequent Respiratory Infection	1
Fatigue	1
Palpitations	1
Infection (Endocarditis)	1

were delivered in hospital, usually by the referring physician; in most cases a reasonably reliable birth history was available. In only one case (131), was there evidence of abnormality. This was 'atelectasis' diagnosed by x-ray on the third day of life. In the others quick and spontaneous crying and good appetite in the first days of life was the rule, though this latter did not necessarily continue.

The findings here, though not so reliably founded as those of Record and McKeown are of some interest in so far as it has not been possible by the method of checking used, to confirm their finding of a high incidence of neonatal difficulty; consequently this study adds nothing to the validity of the suggestion that "asphyxia" at birth may be in some way related to failure of closure of the ductus. It is of interest also that Illingworth in a follow up of infants with documented abnormality at birth including "asphyxia" in the majority, makes no mention of the presence of patency of the ductus.

Symptoms

The majority of the authors (Gross 1953, Levine and Geremia 1947) state that symptoms are few in childhood, except for occasional complaints of dyspnoea, undue fatiguability, and limitation of exercise tolerance.

Gilchrist (1945) while admitting the paucity of symptoms states that comparison with siblings will prove that symptoms do exist by the age of eight or ten years. Ziegler (1952) discusses the condition in infancy, noting congestive cardiac failure in three patients and growth failure in the majority. Keith and Forsyth (1950) hold similar opinions.

The observations in this series are recorded in tables 2 and 3. The parents were questioned as to the child's state of health in the first year, the feeding history and weight-gain were checked in many cases by reference to the 'baby-book' which is fortunately a common, and relatively reliable source of information in the U.S.A.; in only one case was there no symptom.

TABLE 3

ALL SYMPTOMS

	Number	Percentage of al
Frequent Respiratory Infections	19	70
Failure to Thrive	14	52
Poor Weight Gain	13	48
Easy Fatibuability	11	41
Dyspnoea	10 (4 slight)	38
Irritability	8	33
Asthma	2	75
Palpitations	1	38
Infection (Endocarditis)	1	38

It will be seen that frequent upper respiratory infection, failure to thrive, and poor weight gain are the principal troubles. Dyspnoea and easy fatibuability are important but less common. Praecordial pain, reported by Levine (1947) did not occur in this series, but may be a feature in older age groups. One case presented with fever and anaemia which were due to bacterial endocarditis.

In the younger age group three children had symptoms indistinguishable from asthma. Two were seen in a classical attack which was relieved by Adrenalin. This symptom has disappeared following ligation in two of the three children. Each was subject to numerous upper respiratory infections. The incidence seems to be rather high and this combination of lesions has not been seen in other shunts such as atrial septal defect.

The rare symptom of laryngeal paralysis reported by Tileston (1910) did not occur in this series.

The signs

General appearance:

There is no striking appearance to these children. They are not gracile. Pallor is not specific.

In this series growth was markedly impaired in the majority, as seen by the table (4). These children tend to be underweight rather than undersized. Children at the extremes of the age-range under consideration appear to be equally affected. While somewhat at variance with the opinion of others (Brown 1951, Gilchrist 1945) this finding fits well with the status in other cases with left to right shunt (see separate section for fuller discussion). Gross (1952) states that the majority of his cases were of normal development.

As in other types of cardiac flaw, deformity of the chest was seen in six of the twenty-seven cases. A close relationship to cardiac enlargement is observed; this in turn is related to the severity of the condition in general, or possibly to the size of the shunt as in case 131 where a left to right shunt of 10 L/sq metre of body surface existed.

TABLE 5

SIGNS

	Number
Associated Defects	9
Chest Deformity	6
Mental Retardation	2
Anaemia	6
Clinical Cardiac Enlargement	14
Praecordial Systolic Thrill	24
Systolic Murmur Only	5
Gibson Murmur	21
No Murmur	1
Corrigan Pulse	17

Nine cases had associated congenital defects; details of which are given in the first section of this thesis.

The murmur

This was described in masterly fashion by Gibson (1900): many eponyms are current, and Gilchrist (1945) summarizes the clinical variations which may be found in this 'continuous' murmur. The typical late systolic accentuation with a diminished intensity in diastole has been frequently described, and is beautifully illustrated by Levine (1947). A frequent apical systolic murmur is reported by these authors, and Darley and Ravin have reported the frequent coincidence of apical diastolic murmurs.

The continuous quality is due to the pressure gradient which normally exists at all phases of the aortic and pulmonary arterial pulse. This will explain why the murmurs is systolic only in many infants, since the aortic pressure is relatively low at this age; the corollary is that a continuous murmur may become systolic if the pulmonary arterial pressure rises to the level of the aorta. This has been seen in this series (case 18); in this child a murmur initially systolic eventually became continuous. When the child cried, struggled, or unwittingly performed a Valsalva manoeuvre, the bruit was systolic only. More permanent reversal of the murmur, due to the changes in the pulmonary vascular tree has been reported by Johnson (1950). Ziegler (1953) correlates a pulmonary arterial pressure (mean) which is 75% of the aortic mean with the presence of a systolic murmur.

It is theoretically possible for no murmur to exist in this condition. This is rare, but has been reported (Keys and Shapiro 1943). This extraordinary finding occurred once in this series (case 222). This infant had no murmur; this finding was confirmed by phonocardiography (see illustration) which showed splitting of the first sound only. This may be the accentuated sound reported by Leatham (1953) in pulmonary hypertension. At cardiac catheterization extreme hypertension was present in the pulmonary circuit, with a narrow aorta-pulmonary artery pressure

PATENT DUCTUS

PHONOCARDIOGRAMS

1.

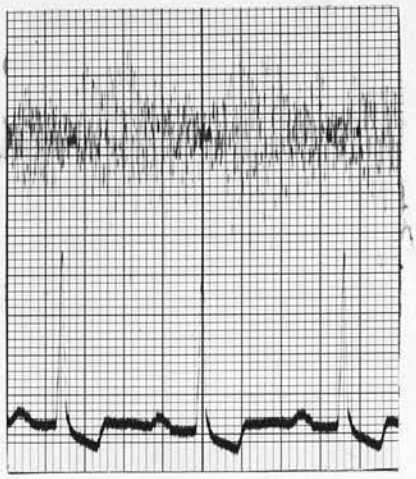
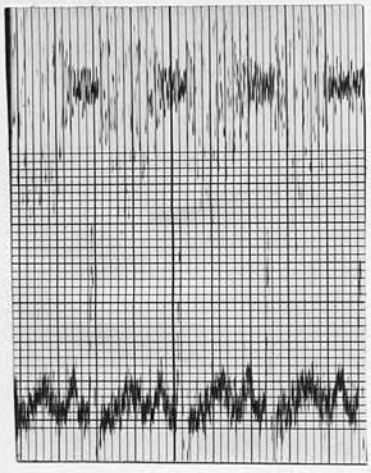


Fig 1. Shows a classical Gibson murmur recorde at the left sub-clavicular area.

2.



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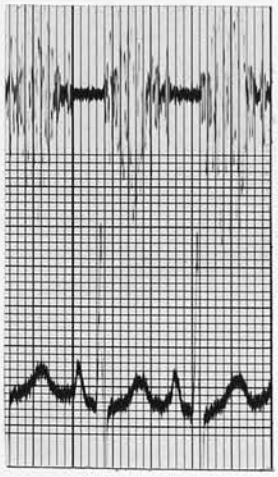


The continuous murmur in this case was audible only in the suprasternal notch (2). Note that the murmur is systolic only in the subclavicular area (3). The second sound is split occasionally.

Supra-sternal notch.

Subclavicular area.

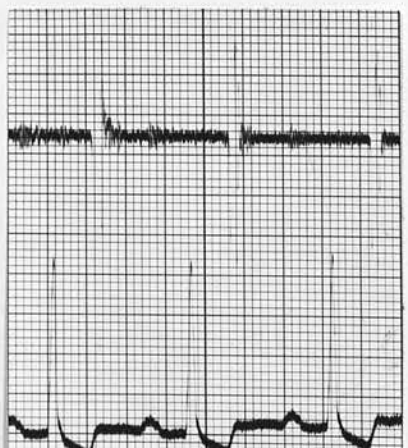


Fig 4. Shows a Durosiez's murmur recorded over the femoral artery.

gradient (mean in P.A. 60; aorta 70). The systolic difference was only 4 mm. of mercury.

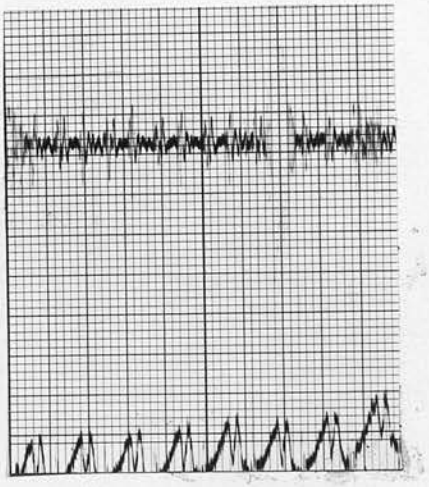
The stage at which the murmur of patent ductus attains its typical quality is of interest. Ziegler (1953) reports an infant aged six weeks with a Gibson murmur, and most of his cases (with a maximum age of 3 years) showed this sign. Conversely the onset of the continuous quality may be a late event and was delayed until age 7 in case 17 of Gilchrist. The maximal age at which a systolic murmur was recorded in this series was 5 years.

In this series all except seven cases had Gibson murmurs of varying intensity. It is not possible to say accurately when the murmur attains its typical quality but in three cases it was established by the ages of 13, 14, and 20 months respectively. These children previously had systolic murmurs only.

The continuous murmur was generally accompanied by the systolic accentuation described by Gibson (1900). It was maximal over the second left interspace; where a systolic thrill was also palpable in most cases. The murmur, especially its systolic element was typically transmitted to the left axilla and the interscapular area. In the smaller children it was readily audible throughout the chest. Two cases had faint apical mid-diastolic murmurs preceded by a systolic the typical 'continuous' quality was absent. This has been noted as an occasional finding by Laubry and Pezzi (1921), Gilchrist (1945) and Levine (1947). No case was found to have the low 'parasternal' diastolic murmur said to be due to pulmonary incompetence (Barber, Magidson and Wood 1950). This was so in spite of unequivocal evidence by cardiac catheterization (case 131) that the pulmonary valve was incompetent. Here the oxygen content of the blood from high right ventricle was increased.

In the infant cases where the murmur was systolic only, this sign was of little value in distinguishing patent ductus from other intra-cardiac shunts. The small size of the chest militates against accurate localization, the point of maximal intensity generally being recorded

PATENT DUCTUS



This phonocardiogram shows no murmur. However a presystolic 'click' is present.

as the second and third left interspaces, with the wide transmission noted above. In five of the seven cases with a systolic murmur an accompanying thrill was present. The second pulmonary sound was accentuated and usually physiologically split. This accentuation was noted in those children with a continuous murmur whose intensity did not obscure the second sound: apical triple rhythm occurred thrice.

The praecordial examination

The apex type was checked upon and recorded in the majority of cases, except in the severely affected infants no deviation from normal was found. In these latter the apex was of the 'tapping' right ventricular type so common in atrial septal defect, (Barber, Magidson and Wood 1950). Cardiac enlargement - sometimes marked - was clinically appreciable in ten of the twenty-seven cases. The thrill is discussed under 'the murmur'. In the older children it was possible to palpate the 'shock' of the enlarged pulmonary artery.

The peripheral signs

In this condition a wide pulse pressure without systolic hypertension is usual (Gilchrist 1945, Taussig 1947); this reflects the degree of leak from the systemic circulation. The table shows how common this is in these children. The difficulty of assessing the true diastolic level by auscultation is considerable in infants, but is incidentally calculated at the time of cardiac catheterization. This was done in several cases here described; a pulse pressure of 56 mm. Hg. was associated with a left to right shunt index of 10 liters (case 131, age 5); in case 142 (age 5 months at catheterization), a pulse pressure of 45 in the aorta was balanced by one of 27 in the pulmonary artery resulting in a smaller shunt.

A Corrigan pulse was common in these children except in the younger group, in whom the pulse pressure (estimated directly) was small. Durosiez's sign was found in those whose other signs made the diagnosis indubitable.

TABLE 6

RADIOLOGICAL FINDINGS (27 CASES)

Cardiac Enlargement (A.P. View)	18 (4 greatly, 10 moderately, 2 slightly).
Chamber Enlargement	
L.V.	5
L.A.	6
R.V.	6
Prominent Pulmonary Arc	24
Plethoric Lung Fields	20
Hilar Dance	5

Radiology

The findings are summarized in the table . Seventeen of the children showed cardiac enlargement in the antero-posterior view. In six, the majority infants, this was very marked. In the others enlargement was only moderate. This is in keeping with the opinion of Gross (1952), who stated that the heart is slightly or moderately enlarged in these children. Ziegler (1953) states that excessive cardiac enlargement is more common in the infant. His cases, like several presented here, were of considerable severity.

Left ventricular enlargement (assessed in the oblique views) occurred in five cases. This is the natural result of the excess of work performed by this chamber. Left atrial enlargement was noted fairly frequently, agreeing with Gross's opinion. In five of the young infants, (142, 111, 222, 223), marked right ventricular enlargement was present. This is somewhat at variance with Ziegler's (1953) opinion that left ventricular enlargement is usual in this age group. The majority of these patients were catheterized and showed marked pulmonary hypertension with resultant rise in right ventricular work. In two the finding was confirmed by angiocardiography, and in one at post-mortem. This case was complicated additionally by a small ventricular septal defect.

Dilatation of the pulmonary artery of varying degree was invariable. In cases 28, 10, and 61 this was the sole radiological abnormality. Increased pulmonary vascular markings of variable degree occurred in the majority.

In fine, most of the cases showed slight cardiac enlargement with a prominent pulmonary arc, and most showed hypervascularity.

The radiological phenomena which occur in some of the severely affected infants comprise; marked cardiac enlargement, principally of the right ventricle; increased pulmonary arc, and hypervascularity. Where the murmur is systolic only, this clinical syndrome is virtually indistinguishable from atrial septal, and some ventricular septal defect

(vide supra). The finding of Ziegler in regard to left ventricular enlargement is somewhat anomalous. At least four of the cases whom he reports as showing this finding have a minimal pressure gradient from aorta to pulmonary artery. By the nature of things the left to right shunt is small in these children, and so must be the increase in left ventricular work. Conversely, it is possible to adjudge by the right ventricular and pulmonary artery pressures which he gives, that the right ventricular work in these cases must be increased; hypertrophy or dilatation of this chamber must follow.

It has already been noted in the section on Tetralogy of Fallot that retro-displacement of the left ventricle may occur in right ventricular enlargement. This results in a spurious 'enlarged left ventricle' when the patient is placed in the left anterior oblique. Eek (1949) has shown the truth of this statement. It is suggested that the x-ray criteria for some severe cases of patent ductus are not yet on an indubitable basis.

Angiocardiography

In view of the frequency with which a sound clinical diagnosis may be made, angiocardiography is of small value in the diagnosis of patency of the ductus arteriosus. The particular value lies in the differential diagnosis from other types of cardiac shunts in infancy.

Dotter and Steinberg (1952) summarize the principal findings: dilatation of the pulmonary arteries, "high" left pulmonary artery, and persistent opacification of the pulmonary vessels when the aorta is filled. Goetz (1951) notes the presence of a 'filling' defect in the left pulmonary artery as a useful sign. The former authors observe however that none of the above described findings may be present in this defect.

Four cases in this series (223, 224, 130, and another) were subjected to angiocardiography. Dilatation of the pulmonary vessels could be seen in all; evidence of right ventricular enlargement was present in two

(223 and 225) and reopacification of the pulmonary circulation by medium from the aorta in three. In one (case 224), the examination was essentially 'normal', though the physical signs were incontrovertible.

This method is of value, though it is not always diagnostic. In case 225 surgery was performed on the basis of the angiocardiogram since the child was deteriorating and a differential diagnosis from atrial septal defect was in doubt. At operation a hugh ductus arteriosus was found. This infant died later, and autopsy revealed a small ventricular septal defect in addition.

Retrograde aortography is of great value in the diagnosis of this condition (Keith and Forsyth 1950), but was not employed in this series.

The electrocardiogram

Schnitker (1940) observes that normality is usual in patency of the ductus. Gilchrist (1945) found left axis deviation in a proportion of his patients who were ten or more years of age. In infancy some cases show left axis deviation and evidence of left ventricular hypertrophy (Ziegler 1952). The same author reports occasional right bundle branch block. Hultgren et al (1953) show incidentially that a right ventricular hypertrophy pattern may occur in some cases with marked pulmonary arterial hypertension.

The table summarizes the findings in the group presented: the majority of the tracings were within normal limits. Six showed left axis deviation, only one (case 55) had evidence of an hypertrophy pattern. Right axis deviation was seen six times, including many of those seen in infancy. The difficulty of establishing absolute criteria for right ventricular 'strain' at this age has been commented on by Ziegler (1951). Only one was considered to show this change. The frequency of left ventricular hypertrophy (on electrocardiogram evidence) reported by Ziegler (1952) could not be confirmed.

In general it may be said that the electrocardiogram has little part to play in the diagnosis of patent ductus arteriosus.

TABLE 7

ELECTROCARDIOGRAPHIC FINDINGS

Normal	18
Prominent Right Axis Deviation	3
Prominent Left Axis Deviation	4
Left Ventricular Preponderance	1
Right Ventricular Preponderance	1

Cardiac catheterization

This method of investigation though seldom necessary to detect this anomaly is of great interest. It is possible to infer the presence of a ductus by the increased oxygen content of the blood in the pulmonary circulation. In a high proportion of cases the ductus may be catheterized direct, as demonstrated by Adams et al (1950). This puts the diagnosis beyond all doubt. The degree of shunt is readily calculable by the Fick principle, and the pressure in the lungs and right heart calculated. This latter is of special importance since it may cause a right to left shunt. Certain cases of this type do not benefit from surgery (Cosh 1953), and cardiac catheterization is the only reliable method of prognosis.

Several children (223, 73, 142, 131 and 222) were catheterized, principally because the diagnosis from atrial septal defect could not be made with confidence. In case 131 the clinical diagnosis was obvious. Two children (224 and 142) had a systolic murmur only, together with evidence of right ventricular hypertrophy and pulmonary hypervascularity. Case 222 had presented with 'diarrhoea', failure to thrive, and anaemia; no murmur was found (see section on 'murmur', and appended phonocardiogram). The heart was enlarged with some prominence of the pulmonary artery; the heart size decreased slightly on correction of the anaemia. All other investigations being unavailing the child was catheterized; the aorta was entered via a patent ductus arteriosus. Marked pulmonary hypertension with a small aorto-pulmonary pressure gradient was present. It is doubtful whether the diagnosis could have been made by any other method; the sole clue to the true diagnosis was moderately enlargement of the heart and a mildly prominent pulmonary conus. The other two infants also had marked pulmonary hypertension with a small pressure gradient into the aorta. Both were successfully operated upon.

Complications

There were happily few. Only one case of bacterial endocarditis if recorded (case 139). This child did well following surgery. The rarity of this complication in this series is in line with the opinion

of Schumacker (1943) who states that endocarditis lenta is rare under the age of twelve years.

No case of tuberculosis was found either by the tuberculin test or by radiography.

Surgery

This will only be commented upon briefly; the first success was reported by Gross and Hubbard in 1938; by 1952 Gross was able to review 525 cases.

Only one case of this series did not have operation. The results in these cases was good, dramatically so in the younger cases with failure of nutrition. One infant died of acute laryngeal obstruction twelve hours after surgery; autopsy revealed a small ventricular septal defect. This of course does not preclude success (Ziegler 1952, case 8).

It is probable that all cases of patent ductus arteriosus should be subjected to surgery. There is some evidence that the younger a child presents with this defect the more serious it is (vide supra; Ziegler 1952). With marked pulmonary hypertension some dubiety as to the results of operation may exist. In three of the infants described here pressures within the aorta and pulmonary artery were measured at the time of operation. It was possible to demonstrate a significant fall in the pulmonary pressure with temporary occlusion. The aortic pressure stayed static or rose a few points. The heart rate slowed in two of the cases. Fortified with these results, the surgeon could proceed confidently to the permanent interruption of the vessel.

In the usual case the pulse pressure decreases after operation. A grade I or II systolic murmur is a common residuum.

Summary

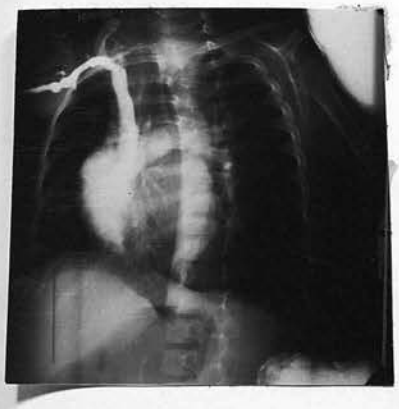
Twenty-seven cases of patent ductus arteriosus are described. Many were infants, and certain problems in diagnosis in this group are commented upon. The clinical, radiological, and electrocardiographic findings are

presented. Some results of cardiac catheterization are given together with a partial evaluation of this method in investigating the atypical case found at early in life.

PATENT DUCTUS ARTERIOSUS

- ANGIOCARDIOGRAM -

(1) 1.4 Secs.



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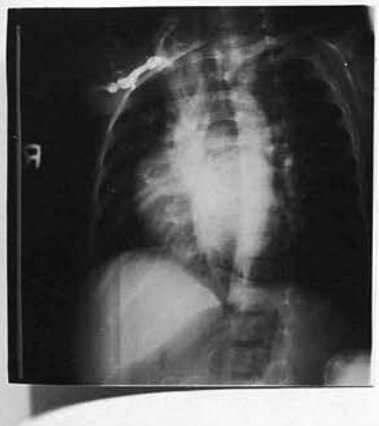

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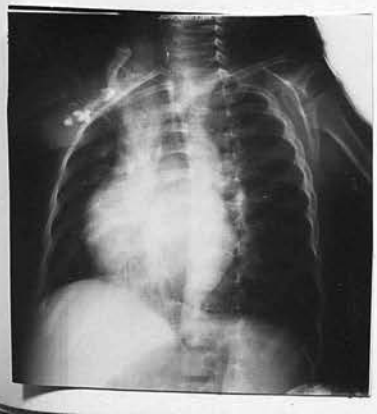


Film 1 shows the right ventricle and dilated main pulmonary artery. The aorta and left ventricle (and pulmonary arteries) are seen in film 2; the right ventricle has cleared by this time. In film 3 the left ventricle is almost empty. The aorta has refilled the pulmonary vessels.

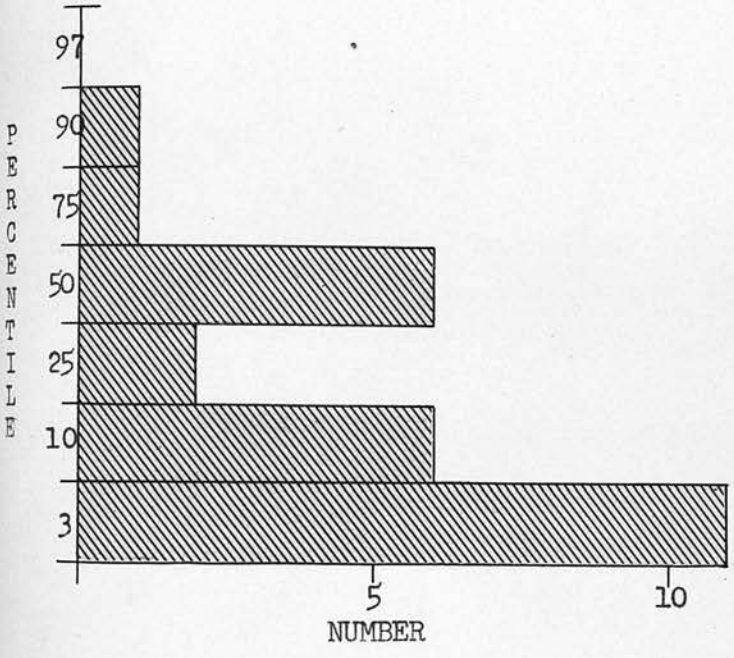
TABLE 4 - GROWTH

HEIGHT AND WEIGHT (27 CASES)

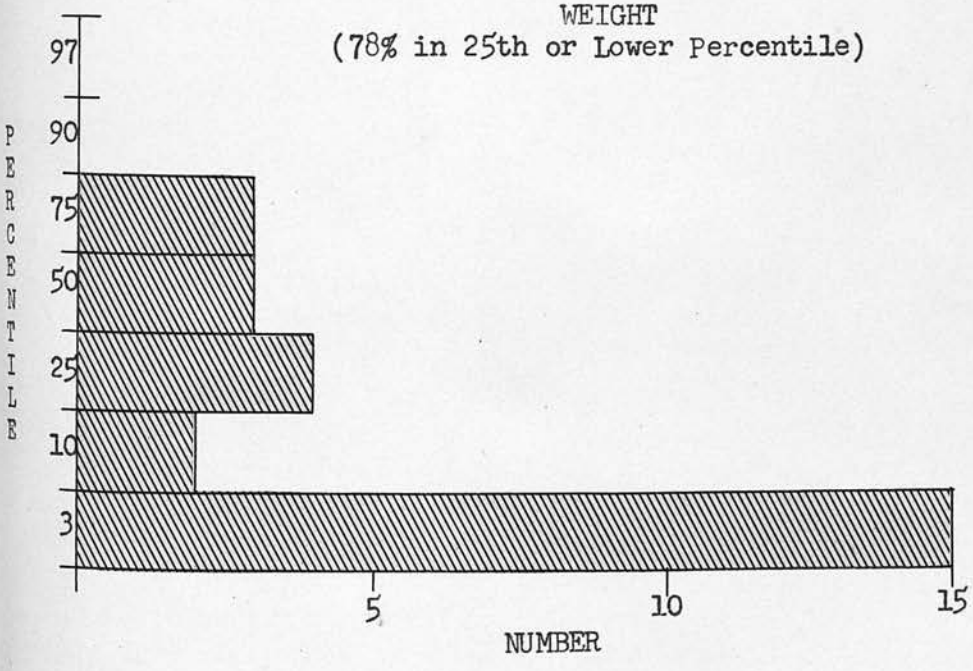
DISTRIBUTION

HEIGHT	PERCENTILE	3	10	25	50	75	90	97
	NUMBER	11	6	2	6	1	1	-
WEIGHT	PERCENTILE	3	10	25	50	75	90	97
	NUMBER	15	2	4	3	3	-	-

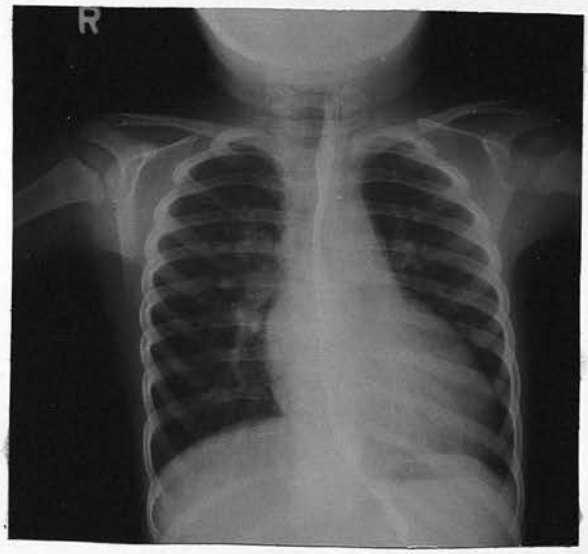
HEIGHT
(70% in 25th or Lower Percentile)



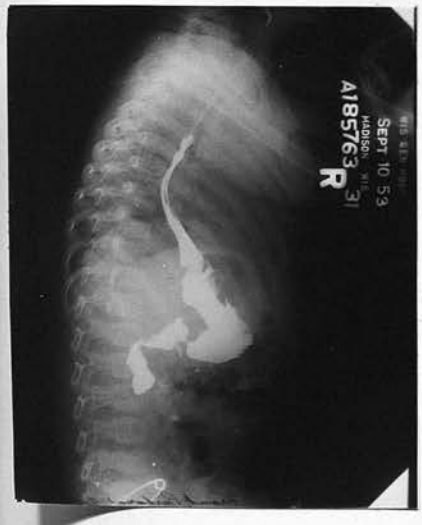
WEIGHT
(78% in 25th or Lower Percentile)



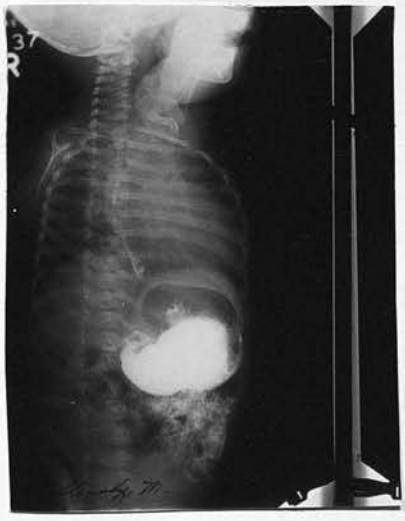
PATENT DUCTUS - X-RAY FINDINGS



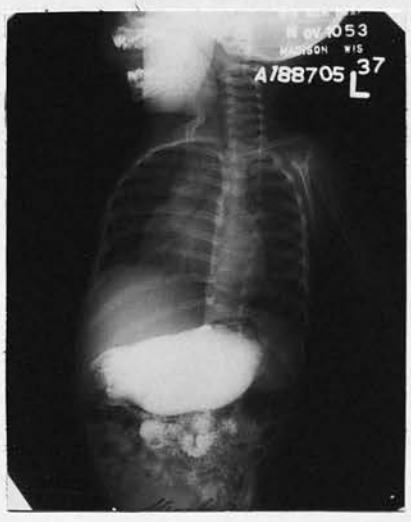
This P.A. film shows some cardiac enlargement, and prominence of the vasculature in the hila.



This R. lateral film shows the prominence of the left atrium.



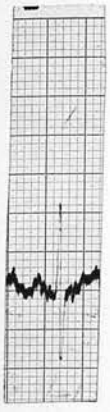
In the R.A.O. the pulmonary artery and right ventricle are enlarged.



This L.A.O. film shows a large left ventricle.

E.C.G. PATENT DUCTUS - AGE ONE YEAR
WITH PULMONARY HYPERTENSION

1



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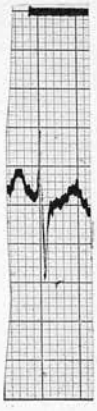

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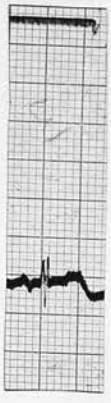


AVR

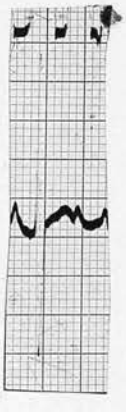
AVL

AVF

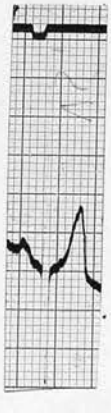
V_1

V_3

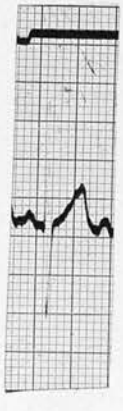
V_4



V_5



V_6



Note the right ventricular prepondenance. The rR' pattern in V_1 suggests incomplete right bundle branch block.

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Section 10

M I S C E L L A N E O U S

A. Mitral Atresia - 1 case.
B. Cor Triloculare Bi-atriale - 1 case.
C. Anomalous Pulmonary Venous Drainage - 3 cases.
D. Common Ventricle with pulmonary stenosis - 2 cases.
E. Idiopathic Pulmonary Dilatation - 1 case.
F. Anomalous Systemic Venous Return - 2 cases.
G. Fibro-elastosis of the aortic valve - 2 cases.

MITRAL ATRESIA

Case Report

This child was admitted at the age of 1 week. The principal complaint was of cleft-palate and hare-lip. He had been cyanotic since birth. Other anomalies included cleft-uvula, dysplastic pinnae, bilateral colobomata and left metatarsus varus.

Examination revealed a cyanotic infant who was very dyspnoeic. The neck was very short; a short systolic murmur was audible in the upper left praecordium.

X-rays of the neck showed congenital fusion deformities (Klippel-Feil) syndrome; the left humerus was also congenitally short. Fluoroscopy showed a large heart with a narrow vascular pedicle in the A.P. view. Pulmonary vascularity was slightly increased.

Progress

The patient remained in a parlous condition. He required continual oxygen. Several episodes of respiratory infection were treated by antibiotics. After 3 months the child developed congestive cardiac failure and died unrelieved.

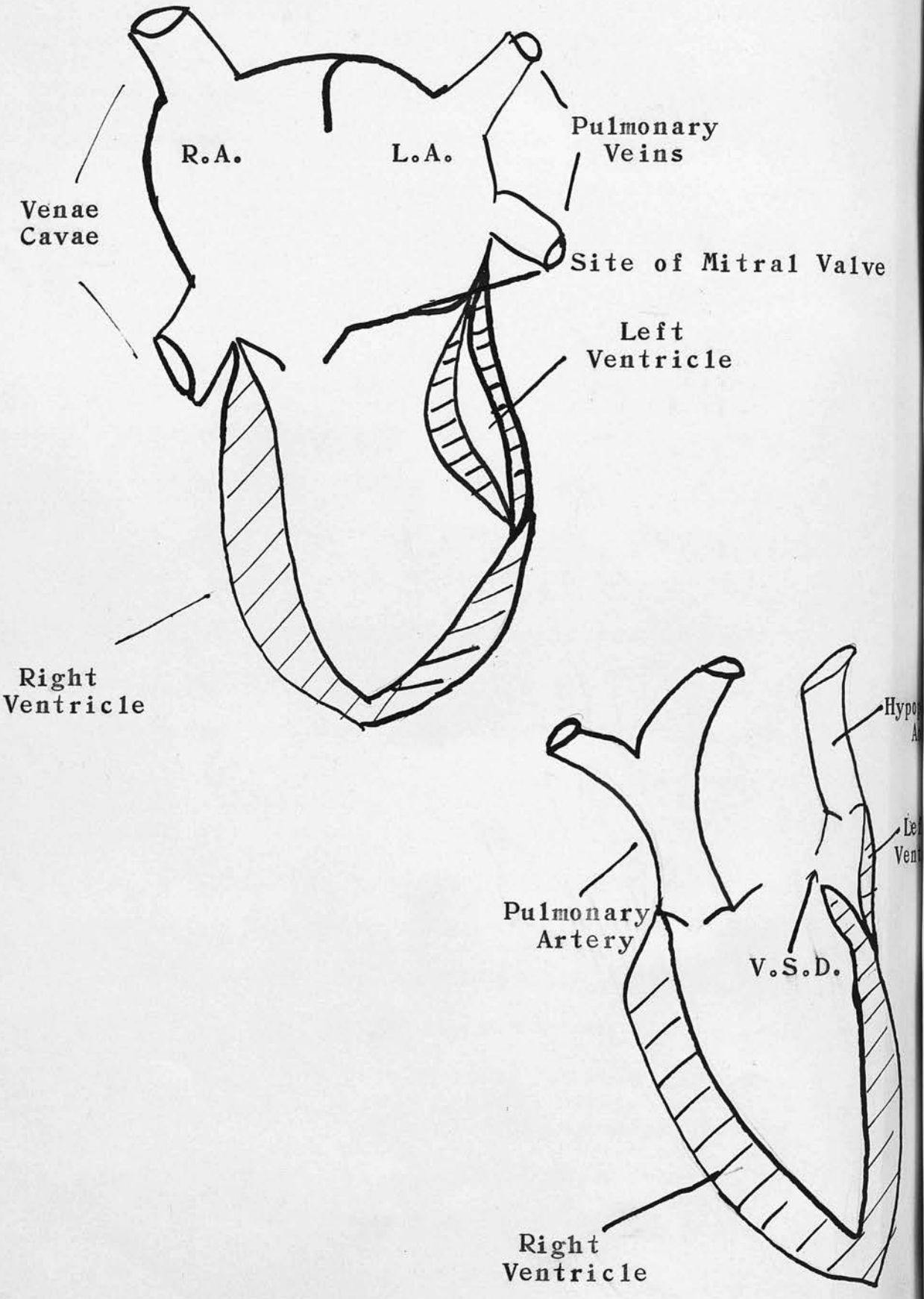
Autopsy

The right auricle was enlarged and received the venae cavae in a normal fashion. A tricuspid valve entered a large right ventricle. The pulmonary circulation was normal. The pulmonary veins entered the left atrium. This chamber communicated with the right atrium by a 1 cm. septal defect. The mitral valve was absent. The left ventricle was tiny and embedded in the right ventricle. The aorta overrode a ventricular septal defect. The ductus was patent. The course of the circulation is outlined in the diagram.

Discussion

Mitral atresia may be primary (as in this case), or may be secondary

MITRAL ATRESIA - DIAGRAM



when a severe aortic lesion is present. In this latter, the mitral valve is generally present to some extent. Physiologically this case is a cor biloculare. The atrial septal defect is essential to existence and is reported in most cases - an exception is recorded by Mackintosh (1926) - the aorta was atretic in this case; the circulation as described by Mackintosh was maintained by an anomalous pulmonary vein entering the superior vena cava. An abnormal vessel connected the left auricle with the superior vena cava. Transposition of the great vessels is a relatively common association (Harris and Farber 1939).

In complete atresia, as in this case, it is suggested that during division of the atrio-ventricular orifice by fusion of the anterior and posterior endocardial cushions that the latter are shifted, to the left. This results in atresia (Brown 1950).

This unusual lesion carries a poor prognosis; the difficulty in differentiating the lesion from transposition is noted.

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COR TRILOCULARE BI-ATRIALE

It should be remarked that a functional cor triloculare may exist in such conditions as tricuspid atresia, mitral atresia, and aortic atresia. The 'disuse atrophy' consequent upon such lesions causes suppression of the ventricle, so that careful search may have to be made for the hypoplastic chamber. Examples of such conditions are given by Brown (1950), and personal cases are described in the appropriate sections of this thesis.

The association of this syndrome with transposition of the great vessles and stenosis of one of them has already been mentioned in a previous section, and a review of many cases is given by Campbell and his associates (1953).

A single case of cor triloculare ventriculare, physiologically a cor biloculare is presented.

Case Report

Case 1

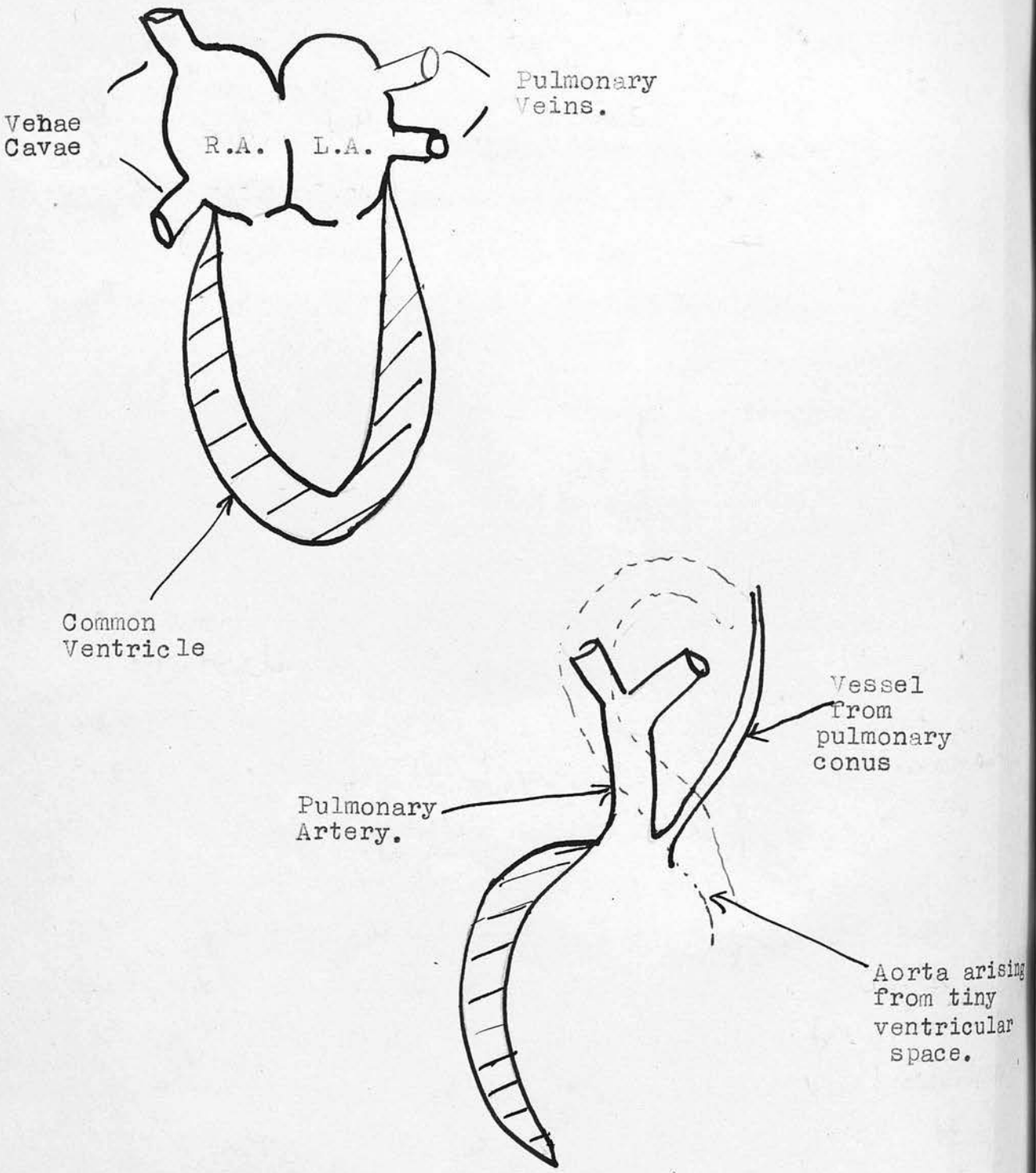
This infant was the product of a normal gestation and delivery. The birth weight was 5½ pounds. Cyanosis had been noted soon after birth. Dyspnoea and failure to gain weight were additional troubles.

Examination revealed a cyanotic, dyspnoeic infant of weight 2.8 kg and height 49 cm; marked lassitude was present. The pulses were rapid, but normal. The heart was clinically enlarged. A systolic thrill was present at the base. The systolic murmur, maximal in the same area was widely transmitted to both axillae and the back. Marked venous distention was present. The hemoglobin was 15.5 grams. Chest films suggested a large heart and some pulmonary atetetasis. No further detail could be obtained from the film available. Unfortunately no electrocardiogram could be obtained before death.

Autopsy

The heart was enlarged. The right atrium received the systemic veins in normal fashion. The tricuspid valve communicated with a

Circulatory Diagram.



ventricle having only a small posterior remnant of the septum; or dissection the aorta was found to arise from a small chamber of 3-5 cc. capacity in the wall of the common ventricle. It was somewhat atrophic. The pulmonary artery arose in normal fashion and had a normal distribution. The conus in addition gave off a moderate sized vessel which ran behind the aorta to be distributed in the neck area. Due to transection in removing the specimen the terminal course of this vessel could not be made out. A probe could be placed through the lower part of this vessel near its origin to demonstrate a connection with the pulmonary artery. A patent ductus arteriosus, was also present. The left atrium was somewhat small, but received the pulmonary veins normally and transmitted blood by way of a mitral valve. An inter-auricular septal defect was also present.

The essential features are reproduced in the diagram. Apart from the anomalous vessel from the pulmonary conus, this specimen is representative of that described by Brown (1950) as "single ventricle with rudimentary outlet chamber, the great vessels being transposed so that the aorta rises from the rudimentary chamber and the pulmonary artery from the single ventricle". It is very similar apart from the anomalous vessel from the pulmonary conus - to the case of Favorite (1934).

The persistent vessel arising from the pulmonary conus is of great interest. Essentially three great vessels were present. Reflection brings to mind the fact that this is the case in the reptilian heart (see diagram). In the lizard for example, the right and left aortae are in relation to the posterior ventricle, and the pulmonary artery to the anterior ventricle. It is postulated that in the heart described the vessel arising from the area of the pulmonary conus represents a persistent right aorta; the aorta proper is that arising from the suppressed outflow tract, secondary to the failure of septal formation. Undoubtedly the anomaly of bulbar development which is

associated failure of septation contributed to the vascular arrangement here, since fusion of the truncal valves leads to the formation of the two aortae and the pulmonary artery in the reptile.

Spitzers emphasis upon failure of normal septation process is perhaps of some significance here. According to this, in transposition the "aorta" really represents the primitive reptilian vessel. It is not perhaps too far-fetched to conclude that this was so in the case of presented. The anomalous vessel from the pulmonary conus has failed to represent the aorta (as in transposition) because of failure of complete suppression of the "true" aorta - here hypoplastic - and left ventricle.

Summary

This case of common ventricle and anomalous pulmonary vessel probably represents an atavism which is comparable to the reptilian heart.

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ANOMALOUS PULMONARY VENOUS DRAINAGE

Winslow (1739) probably described the first case of this interesting condition. Abbott (1936) describes four cases with associated anomalies. Brody (1942) reviewed the literature.

Partial anomalous pulmonary venous drainage is relatively common (Smith 1951). Several such cases (e.g. in tricuspid atresia) are mentioned incidentally in the subsections of this thesis.

The incidence of this type of partial anomaly is unknown, and must remain so until the heart and lungs are removed en bloc at autopsy. The routine manoeuvre of removing the heart at an early stage renders further investigation of pulmonary venous drainage impossible.

Developmental Basis

The primordiae of the lungs, larynx, and tracheobronchial tree are derived from division of the fore-gut, which is enmeshed by the splanchnic plexus and supplies the respiratory organs already mentioned. This splanchnic plexus drains into the umbilicovitelline venous system and the hepatic sinusoids. These of course are the precursors of the venae cavae, coronary sinus, portal veins, innominate and parts of the subclavian veins. Thus the pulmonary vein is indirectly connected to the heart through the umbilicovitelline system or its results.

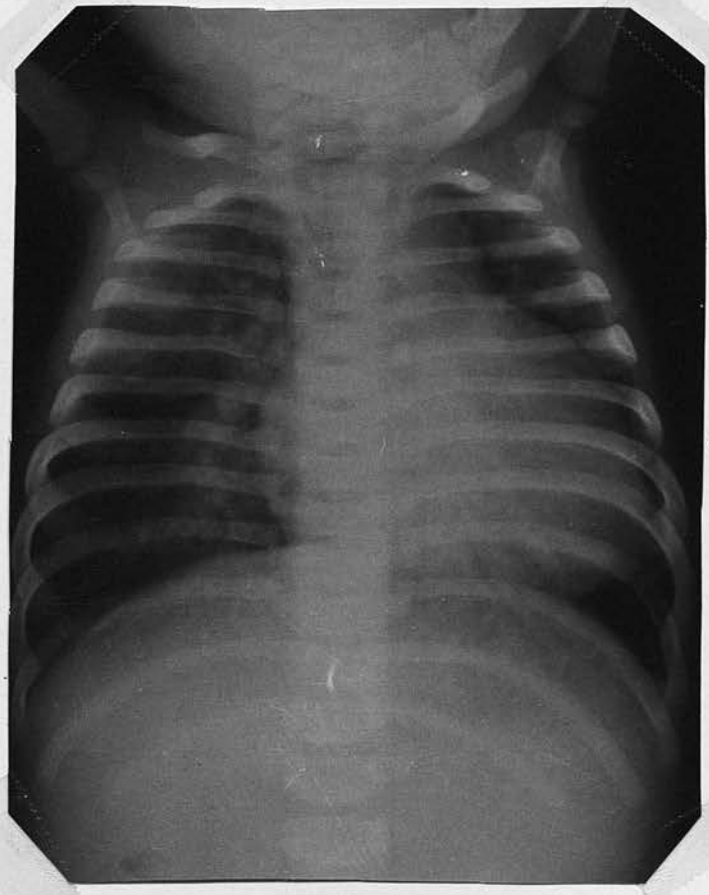
The work of Auer has shown that the outpouching of the sino-atrial region which becomes the left atrium makes connection with the splanchnic plexus; this as already mentioned is the vascular drainage of the primitive lung. Later the connections of the splanchnic plexus as detailed above, are obliterated, and a direct pulmonary venous drainage to the heart comes into being.

If the outpouching of the sino-atrial region fails to make contact with the lung, then the only connection possible is by way of those mentioned in the first paragraph. Failure of involution of these may cause anomalous drainage from the lung into the systemic or portal venous

Anomalous Pulmonary Venous Return.

- Chest Film -

Case I.



The heart is enlarged, and the right lung field appears Hypervascular.

circuit. Edwards (1953) suggests that in cases which some or all of the pulmonary veins enters the right atrium, that the primary lesion is anomalous atrial septation - the septum is laevoposed. Fuller details may be found in the article by Edwards (1953).

Clinical features

A general review of these is given by Keith (1954). Cyanosis was noted to inconstant. A murmur was occasionally absent, more usually it was short and systolic in time. A continuous murmur (venous hum) was heard in cases where the pulmonary veins drained into the left innominate vein.

Case Reports

Case 1

Anomalous pulmonary venous drainage into the right atrium. This 6 month old white male was the 1st child of healthy parents. The pregnancy was normal. At birth the child was generally cyanotic and required oxygen for a few days. This then lessened, and only slight cyanosis of the face and lips was noted until shortly before admission. Slight dyspnoea had been noted, but weight gain had been good. Examination revealed the length to be 53.5 cm. and the weight to be 10 pounds 10 ounces. The face and lips were cyanotic at rest. This became generalized on crying. The veins were prominent and early clubbing had appeared. The feet were puffy; and the liver enlarged.

A short systolic thrill was palpable in the prone position. The apex was displaced indicating cardiac enlargement. A short systolic murmur, maximal at the mid left sternal border was present and transmitted to the left axillae and back. The second pulmonary sound was weak. There was no diastolic or triple rhythm. Fluoroscopy showed generalized cardiac enlargement with the left auricle and ventricle showing the more marked changes. The lung vascularity was increased, and prominent pulsations were observed. An electrocardiogram showed right heart dominance. A mild anaemia was present.

The clinical diagnosis was atrial septal defect, possibly with associated pulmonary stenosis.

An angiocardiogram was carried out and showed opacification of the right heart, aorta and pulmonary artery simultaneously. This was interpreted as showing an overriding aorta or an atrial septal defect; the latter diagnosis was favoured.

Progress

The child developed frank congestive failure which was unrelieved by digitalis or mercurials.

Autopsy

The right auricle was greatly dilated and received the venae cavae, and also all the pulmonary veins. It communicated with a small left auricle by an 0.5 cm. septal defect. The right ventricle was enlarged, as was the pulmonary artery.

Comment

This is a typical case of complete anomaly of the pulmonary venous drainage. The slight cyanosis noted early in life, the cardiac enlargement and systolic murmur are the signs noted by Keith (1953). The fluoroscopic findings are readily confused with a left to right shunt. Keith states that a QR pattern in the right praecordial leads is usual in this condition. This was seen in V_1 in one of the frequent electrocardiograms taken in this instance.

Case 2

Pulmonary veins draining into the inferior vena cava. This 10 day old female was the product of a normal gestation. She was cyanotic and dyspnoeic at birth; food intake had been poor.

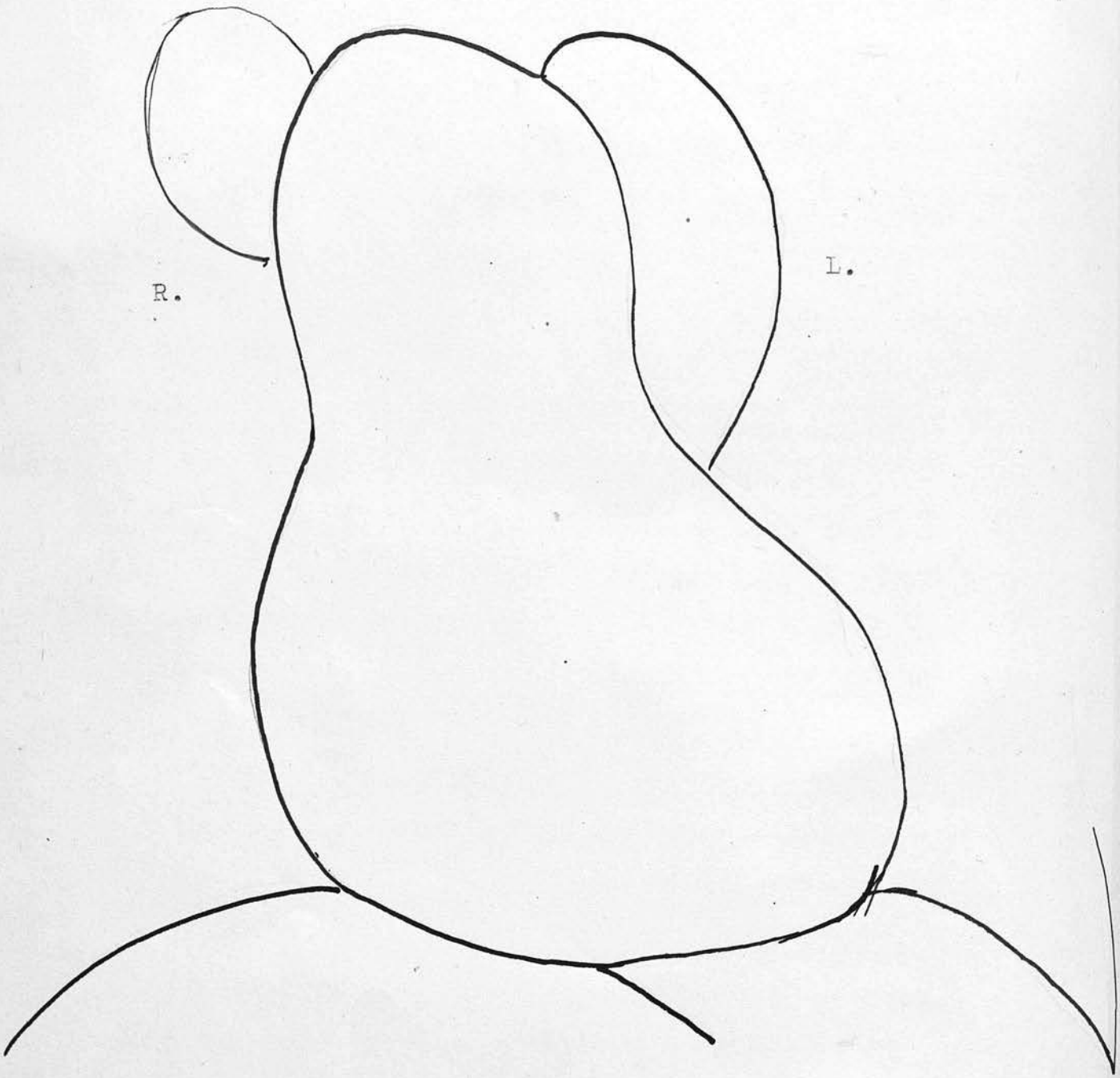
Examination

There was cyanosis of the lips, fingers and toes; this increased on crying. The heart did not seem enlarged. There was a soft systolic murmur. The child was moderately dyspnoeic. Fluoroscopy revealed the heart to be normal in size and shape, except that the pulmonary arc was

Anomalous Pulmonary Venous Return.

Tracing of Orthodiagram.

Case 3.



somewhat concave. An electrocardiogram showed right axis deviation.

Progress

The infant's cyanosis increased and he was placed in oxygen. He expired suddenly at the age of 21 days.

Autopsy

The pulmonary veins formed a common trunk which coursed posterior to the heart to enter as a large vessel into the inferior vena cava. The atrial septum showed a patent foramen secundum. The right ventricle was moderately enlarged.

Comment

This unusual case is undoubtedly due to persistence of the foetal connections between the lung veins and the systemic veins. The defect caused cyanosis at birth and rapid exitus.

Case 3

Anomalous pulmonary venous drainage into the right subclavian or superior vena cava. This 4 year old boy had a history of frequent respiratory infections, delay in gaining weight, and easy fatiguability.

Examination

There was duskiness of the lips and nail beds. His chest was deformed. The heart was clinically enlarged. A systolic thrill was present at the 3rd and 4th left interspaces. A corresponding systolic murmur was transmitted to the left axillae and back. At the pulmonary area the murmur had a to and fro quality.

An electrocardiogram suggested right ventricular envolvement.

Fluoroscopy

This showed considerable cardiac enlargement. In the upper aspect the bilateral was a bizarre density which pulsated.

Diagnosis

Anomalous pulmonary venous return.

Comment

Unfortunately this child was not catheterized. The diagnosis was made on clinical grounds only. The x-rays findings are typical of those recorded by Keith (1952); similarly a diastolic murmur was recorded in 4 of his 6 cases.

Discussion

Three cases of anomalous pulmonary venous drainage are presented. Two were proven at autopsy. In the other the diagnosis depends on the clinical and x-ray findings. Several other cases of partial anomalous drainage from the lung are presented in this thesis. Probably most cases of this type are of little clinical significance. The diagnosis of the more complete types possible in those where the veins drain into the left subclavian vein or innominate. This depends on the bizarre supracardiac shadows seen by x-ray whose significance was established by Oram (1953) and Keith (1954).

The diagnosis in other types may be suspected clinically but should be confirmed by cardiac catheterization. This will reveal an unusual jump in the oxygen content of the venous blood depending on the site of drainage. If this is in the great veins there is little difficulty provided appropriate specimens are taken. If the drainage is directly into the right atrium or coronary sinus much difficulty may be encountered, since the associated atrial septal defect is given sole responsibility for the haemodynamic findings. Only if dye techniques as described by Swan et al (1953) are used will the true state of affairs be realized. This is true even if the pulmonary veins are entered since it is difficult to know in some cases if the left atrium has been traversed or not. Surgical treatment has been reported in partial anomalies venous drainage by Mankin and Burchell (1953). Keith (1954) records three other cases, all of whom died. In spite of this, operative reapposition of the pulmonary veins should be considered in all complete cases, as the prognosis is very guarded.

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Oram, S., Gardner, F.,

COMMON VENTRICLE WITH PULMONARY STENOSIS

This useful subdivision of 'cor triloculare' was described by Campbell and his colleagues in 1953. The clinical importance lies in the close resemblance to the tetralogy of Fallot. However, the pulmonary stenosis may be considered a relatively beneficial condition and surgery (as anastomosis of the systemic and pulmonary circuits), is not entirely advisable.

The failure of formation of the ventricular septum gives rise to a large common chamber which receives both atrio-ventricular valves. Less commonly (as in case 6 of Campbell et al), a single A-V orifice may enter the ventricle. The authors already cited state that remnants of the bulbus cordis may cause obstruction of the outflow tract in this condition. Equally the complex process of great vessel formation is disturbed, and transposition is a frequent concomitant. This occurred in the majority of the cases reviewed by Campbell and his associates.

Other cases have been reported by Brown (1950) and Taussig (1939). The former authority's case had left axis deviation but otherwise bore a close resemblance to the tetralogy of Fallot.

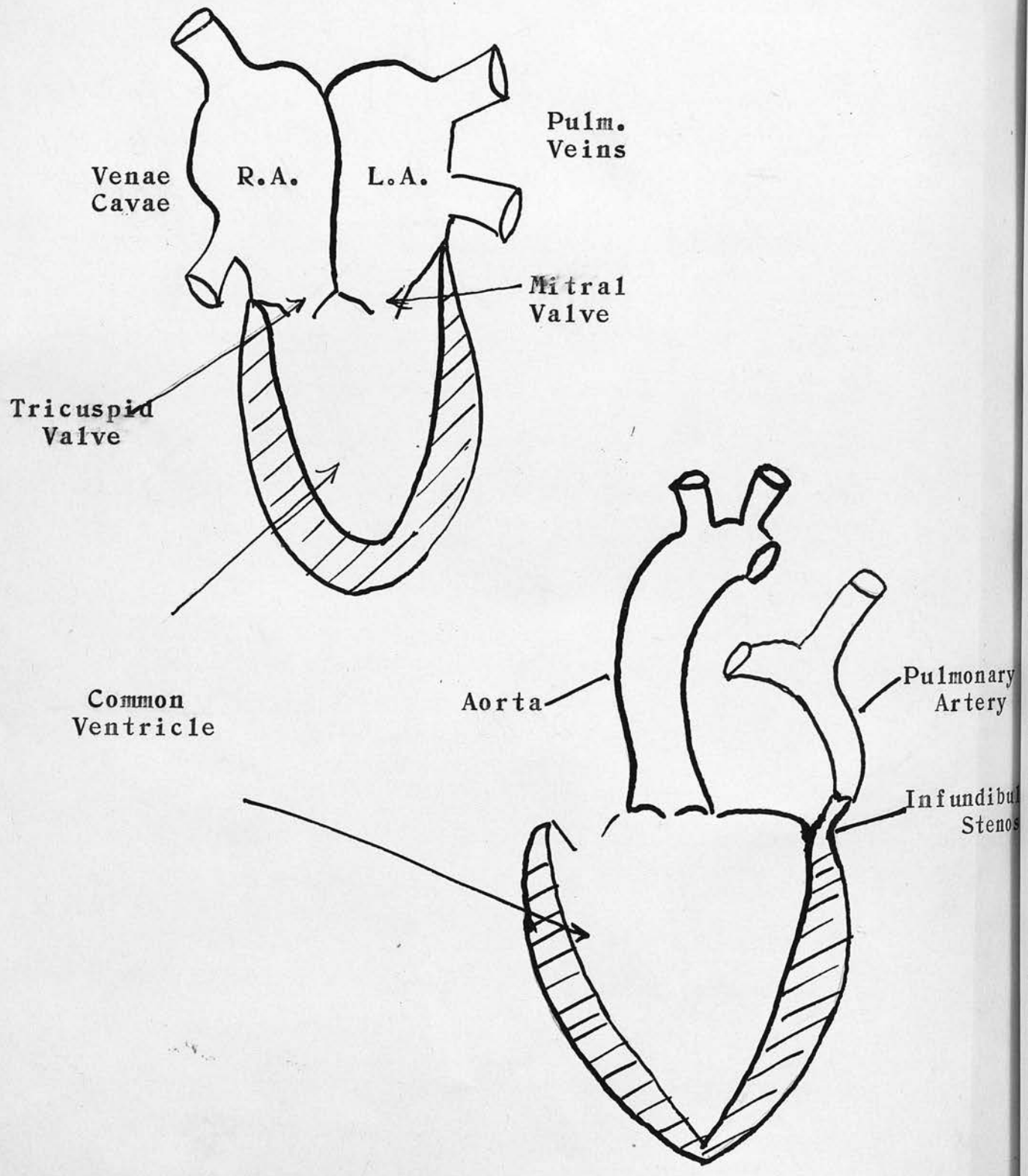
Case Reports

Case 1

This boy, aged 2½ years at admission had been cyanotic since the age of one month. Dyspnoea and frequent respiratory infections had also been observed. Examination revealed a stunted boy (weight 10 kg, height 83 cm), with generalized cyanosis which was maximal in the lips, face, and ears. Marked clubbing was present in the fingers and toes. The chest showed a bulge in the upper left chest with well marked Harrisons' sulci. A systolic thrill was felt at the left sternal border at the 2nd and 3rd interspaces. A loud (grade IV) systolic murmur maximal in the same area was transmitted to the left axilla and back. The second pulmonary sound was single. The heart did not seem enlarged to clinical examination. Paroxysmal dyspnoea with loss of consciousness

PULMONARY STENOSIS WITH COMMON VENTRICLE

CASE 1 - CIRCULATORY DIAGRAM



became a frequent feature, and the child perished during such a seizure. Moderate polycythemia (15.8 gms.) was present. The electrocardiogram showed large 'P' waves, and right axis deviation. The chest films showed marked pulmonary hypovascularity. The apex was elevated and the pulmonary arc concave. The whole picture suggested a severe tetralogy of Fallot.

Autopsy

The systemic veins drained normally into a dilated right atrium. A normal tricuspid valve entered a ventricle. No trace of a ventricular septum was present except for a narrow muscular ridge on the posterior aspect of the chamber. The left atrium received the pulmonary veins in a normal fashion; the mitral valve was complete and entered the common ventricle.

The aorta (giving off a normal coronary circulation) arose from the right of the ventricle and broke up into its normal branches. The pulmonary artery arose from the ventricle along the antero-superior surface. Its valve was bicuspid and narrowed. An infundibular stenosis was also present. The ductus arteriosus was closed.

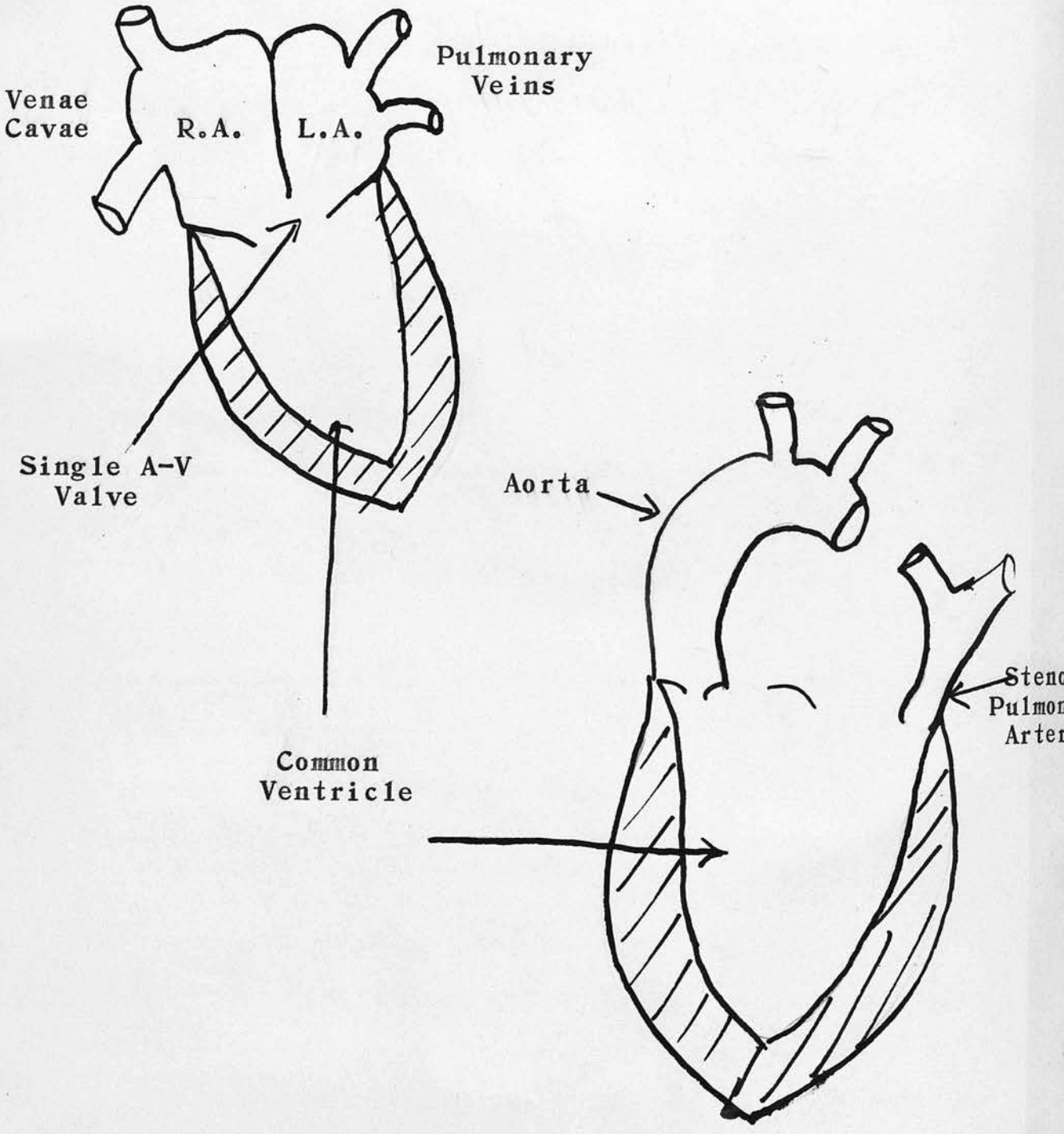
Case 2

This male, aged one year at the time of admission had been cyanotic from the age of 6 weeks. A dyspnoea and failure to gain weight had been noted from this time. He had required admission to another hospital apparently for cerebral thrombosis. He had suffered frequently from respiratory infection.

Examination revealed an stunted child (weight 6 kg.) who was intensely cyanotic. There was extreme clubbing and some chest deformity. The pulses were normal, but the heart was enlarged to the anterior axillary line. A thrill was palpable at the left sternal border, and a corresponding thrill maximal over the 2nd to 3rd spaces was transmitted to both axillae and the back. The second pulmonary sound was loud and single. A loud third heart sound was present. Marked polycythaemia

PULMONARY STENOSIS WITH COMMON VENTRICLE

CASE 2 - CIRCULATORY DIAGRAM



(18.0 gms.) was found. An electrocardiogram showed a vertical axis with marked peaking of the 'P' waves.

Chest x-ray showed a large "boot-shaped" heart with elevation of the apex. The right ventricle was apparently enlarged in the oblique view. The pulmonary arc was concave, and the lung-fields oligaemic.

The childs' condition deteriorated, so that a Blalock procedure was carried out. The child died soon after.

Autopsy

The ventricle was dilated and hypertrophied. The aorta arose from this ventricle as did the pulmonary artery. The latter was severely stenotic. The right atrium received the systemic veins in a normal fashion and communicated with the left atrium by a small (3 cm) septal defect (foramen secundum). The tricuspid valve was normal. The left atrium was small but received the pulmonary veins normally. No trace of a mitral valve was found, and there was no evidence of a left ventricle.

From the anatomical point of view this lesion consisted in a single ventricle, with dextroposition (transposition) of the aorta. The left ventricle was suppressed, probably as a result of the absence of the mitral valve.

The subclavian pulmonary anastomosis was patent, but a thrombus had occluded the upper subclavian.

Discussion

These two cases are presented together because of their essential similarity to the tetralogy of Fallot. Case 1 is almost identical with most of the six cases presented by Campbell et al. Case 2, was similar as far as the existence of the single ventricle with pulmonary stenosis was concerned. The mitral atresia (or absence), however distinguished the condition. Perhaps this case might have been suspected clinically in view of the enlargement of the heart which is relatively rare though not unknown in the tetralogy (Taussig 1947). From the

radiological point of view, the pulmonary oligaemia was the significant sign which urged surgery. This is true of course even for transposition with pulmonary stenosis (Astley and Parsons).

In retrospect, the only sound surgical procedure in case 2 would have been deliberately to increase the size of the septal defect and thus divert more oxygenated blood to the aorta. It would appear that a pulmonary valvulotomy would not have been successful in view of the short area of atresia distal to the valve.

Cardiac catheterization was not carried out in either case. Perhaps this would have been a useful investigation in case 2, in so far as the pulmonary stenosis might have been demonstrated, or indeed the single ventricle suggested as in the case of Deuchar (1952) who claimed to outline the chamber by multiple views of the cardiac catheter. It is unlikely that the mitral atresia would have been elicited even if the left atrium had been entered. Generally failure to enter the left ventricle is attributed by modest wielders of the cardiac catheter to their own lack of dexterity rather than absence of the mitral valve.

As in the cases of Campbell et al, the electrocardiogram in these two cases showed large 'P' waves. These of course may be found in true tetralogy of Fallot, atrial septal defect and pulmonary stenosis, and occasionally in tricuspid atresia. It is therefore a non-specific finding. The finding of right axis deviation in case 1 argues that conducting tissue was present though the septum was apparently only a vestige. This anomaly was previously noted and appreciated by Campbell et al (1953).

The physical signs as noted here are no different from those in many other types of cyanotic cardiac flaw. Campbell et al. similarly found no specific signs. Angiocardiography was not attempted in the two cases presented. The authors already cited however, found this an unrewarding manoeuvre.

Summary

Two cases of single ventricle with pulmonary stenosis are presented: one was complicated by absence of the mitral valve and suppression of the left ventricle; the aorta in this case arose from the common ventricle. The superficial resemblance of these cases to the more common tetralogy of Fallot is noted. The difficulty of full ante mortem diagnosis is commented upon.

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IDOPATHIC PULMONARY DILATATION

One case of this interesting condition was encountered. It is mentioned principally as an example of the trouble in differentiating this lesion from an intracardiac shunt, and will take the form of a case report.

This six year old white male presented with a complaint of 'cardiac murmur'. Questioning revealed that he suffered from transient loss of consciousness which though unaccompanied by convulsion, suggested epilepsy. The previous history was clear apart from some tendency to winter coughs. The murmur had been discovered incidentally during a pre-school examination.

Examination

Weight 45 pounds, height 46 inches. The relevant findings were confined to the cardiovascular system. The pulses were normal. Praecordium showed no deformity, and the apex was normal in type. No thrill was present. A loud systolic (grade IV) murmur was maximal over the 2-3rd left interspaces, being well transmitted to the left axilla and back. The second pulmonary sound was widely split. There was triple rhythm.

Fluoroscopy

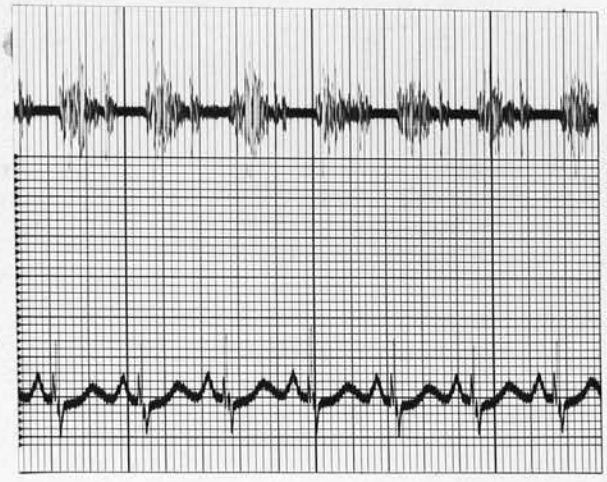
This revealed almost aneurysmal main pulmonary arteries, with marked pulsation. Suggestive enlargement of the right ventricle was seen in the obliques. The aorta was readily seen. The electrocardiogram was normal as was the blood count. An electroencephalogram supported the diagnosis of epilepsy. Clinical impression was of atrial septal defect.

Cardiac Catheterization (Table 1)

Pressures and oxygen contents were normal. No evidence of atrial septal defect or patent ductus arteriosus on repeated probing of atrial wall and outflow tract. It was possible to pass the catheter into

IDIOPATHIC PULMONARY DILATATION

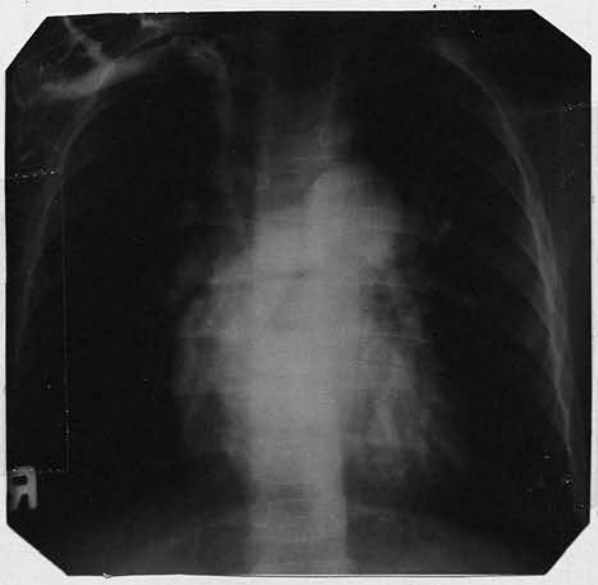
PHONOCARDIOGRAM - BASE



This tracing shows the systolic murmur and split second sound. These findings are also frequent in atrial septal defect.

Idiopathic Pulmonary Dilatation.

Angiocardiogram.



Note the huge Pulmonary artery.

the main pulmonary artery with a large coil in it. This suggested that the vessel had a large calibre.

Calculation revealed normal right and left ventricular work. The pulmonary and peripheral resistances also were normal.

Conclusion from catheterization - physiological study; some evidence of dilated pulmonary artery.

Angiocardiogram

The contrast medium followed a normal course through the right heart to outline the tremendous pulmonary artery. No other pathology was delineated.

Discussion

Superficially the murmur and presence of a split pulmonary second sound suggested an atrial septal defect (Barber, Magidson, and Wood 1950). Some support of this was lent to this by the appearance of the pulmonary arteries at fluoroscopy, though the presence of a readily visible aortic knob is unusual in atrial septal defect. The absence of any shunt at cardiac catheterization, and the demonstration of the huge pulmonary artery however, clinched the diagnosis as 'idiopathic' pulmonary dilatation.

Other conditions which might conceivably be considered are: pure pulmonic stenosis, since post-stenotic dilatation is a common occurrence in this condition (Brock 1952); the presence of the widely split second sound is against this, as is the absence of a thrill: The pullback at catheterization definitely excluded this.

Many cases reported in the literature have suspicious validity. This is the opinion of Greene et al (1949) who reviewed the literature and added four well-documented cases of their own.

Cyanosis and dyspnoea occurred in the cases of Sutherland (1923) and Cautley (1920), though the four cases of Greene and his colleagues were essentially symptom free. The case here reported falls into the latter group; there is little difference in the physical signs except that the second pulmonary sound was widely split. It is reported

Table 1

Catheter Position	Pressure mm. Hg.		Volumes % Oxygen		
S.V.C.	-1/-3 M = -1.2		12.0	)	
			x2	)	11.7
I.V.C.	-1/-3 M = -2.1		11.5	)	
RA (HI)	-2/-4 M = -2.4		12.1		
RA (LOW)	-2/-4 M = -3		12.1		
RV (LOW)	19/-4.5		12.1		
RV (HI)	17.2/-5.8 SM=7.1		12.6		
R.P.A.	8.5/3.8 M=5.1	)	12.6	)	
		)		)	12.1
L.P.A.	12.5/5.7 M=9	) 6.2	11.7	)	
		)			
M.P.A.	6.7/3.8 M=4.6	)			
RPA (WEDGE)	0/-2 M = -0.3				
R.F.A.	74/51 M = 58		14.9 = 93.6% Saturation		
Oxygen Capacity			16.3		
Pulmonary Vein O_2 (Assumed 95%)			15.1		

Systemic Flow = 3718

as "accentuated" by Greene et al. The fluoroscopic finding of right ventricular enlargement is in keeping with the findings of Kouvilsky (1942), though the prominent aorta in this case was not reported by Oppenheimer (1933).

Summary

A case of idiopathic dilatation of the pulmonary artery is presented. The diagnosis was proven by angiocardiography and cardiac catheterization. A superficial resemblance to some cases of intracardiac shunt is noted.

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ANOMALOUS SYSTEMIC VENOUS RETURN

Two cases of this interesting lesion were studied. One is still alive, the diagnosis having been made by angiocardiography; in the other the diagnosis was verified at autopsy.

Reports:

Patient 1

This male infant was admitted at the age of six months with a complaint of dyspnoea. Pregnancy and delivery had been normal; at the age of six weeks the infant had a bout of dyspnoea, which was accompanied by rib-retraction. A systolic murmur had been heard at this time.

On examination he was an anxious-looking, under-sized child with rapid deep breathing, and slight cyanosis.. There was no clubbing. The sternum was rather protuberant. The heart was clinically enlarged; a systolic thrill was felt over the 3-4 left interspaces with a systolic murmur maximal in the same area. The second pulmonary sound was loud. An electrocardio-gram showed peaking of P_1 and P_2 with right axis deviation; x-rays showed general cardiac enlargement, principally of right ventricular origin.

Progress: The infant developed paroxysmal dyspnoea and died suddenly during such an attack.

Autopsy: The heart was enlarged. Two venae cavae

were present, one draining into each atrium. The foramen ovale was patent, and the ventricular septum was deficient (0.5 cm.) in its upper part. The pulmonary artery was dilated. The left carotid was anomalous - it rose from the innominate. A large horse-shoe kidney was present. Microscopy showed sclerosis of the adventitia and media of the pulmonary vessels.

Summary:

This case of congenital heart disease had dyspnoea, interference with growth, and cyanosis. Paroxysmal dyspnoea and death supervened. Autopsy showed a double vena cava, one of which entered the left atrium.

Patient 2

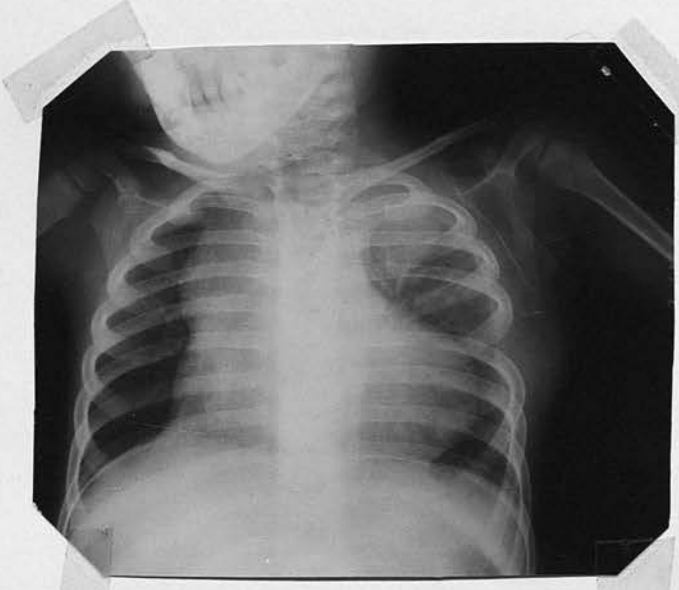
This female child had been observed to the age of three and a half years. She was severely disabled. The pregnancy had been complicated by appendicectomy in the first trimester.

The infant was cyanotic at birth and this had steadily increased. Weight-gain and growth had been poor. She was dyspnoeic at rest, and paroxysmal attacks had occurred.

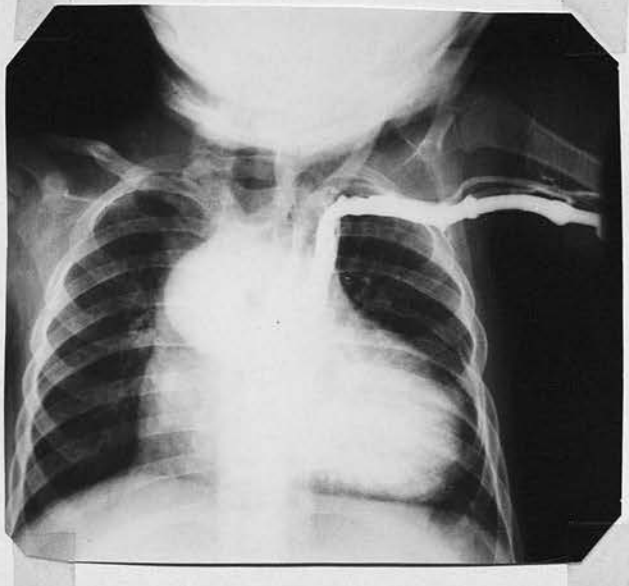
Examination revealed a cyanotic, undersized girl with clubbed fingers and toes. The heart was clinically enlarged, and a soft systolic murmur was heard.

Anomalous Systemic Venous
Drainage.

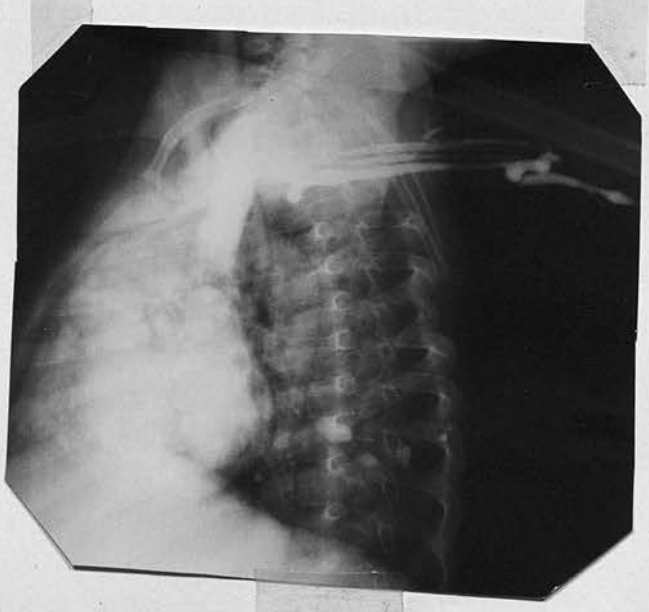
Case 2.



1. Heart.
P. A. View.



2. P.A. Angio-cardiogram.
The medium enters the left heart from a left superior vena cava.



3. The same.
Oblique view.

X-rays showed enlargement of the heart with elevation of the apex (see plate). The superior mediastinum was widened. The lung vascularity seemed normal. The E.C.G. showed inversion of the "P" waves in leads 2 and 3. No definite "strain" pattern was present; polycythaemia was confirmed.

Angiocardiography (see plate), was carried out through the left arm. This showed immediate opacification of the left atrium, ventricle, and aorta.

The provisional diagnosis was of anomalous systemic venous return through a left-sided superior vena cava.

Discussion

These are examples of a rare anomaly. The persistent left superior vena cava represents the structure which usually remains as the vestigiae oblique vein of Marshall. This anomaly entering the right heart is not unusual, and may be found fairly frequently at the time of cardiac catheterization. While a nuisance in this procedure, it is without clinical significance.

The severity of the condition when the systemic veins enter the left heart is illustrated by these two case reports. Abbott (1947) reports one of the few similar cases, and comments that the use of

angiocardiography offers the only clinical method of diagnosis, as in case 2 here.

It would appear that perhaps some cases might be benefited by re-position of the anomalous vein into the right heart, as seems possible with anomalous pulmonary veins (Kirklin 1953). In the obscure case of cyanotic congenital heart disease, angiocardiography through the left arm may be diagnostic, and passage of the cardiac catheter will confirm the lesion. The opposite arm may be similarly explored to see if a right superior vena cava is additionally present.

References

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CONGENITAL AORTIC STENOSIS DUE TO ENDOCARDIAL FIBRO-ELASTOSIS

Several cases of this interesting condition have been reported (Brown 1934; Du Shane & Edwards, 1945). Two further cases are here described and discussed.

Case 1

Clinical Features

This child was the product of a pregnancy complicated by 'influenza' at five months. Birth was normal, the weight being 6 lb. 14 oz. Nothing abnormal was seen until the age of five weeks when he was noted to be breathless, and began to have episodes during which he was pale, sweating, and "passed out". The child refused to eat thereafter. He was put in a local hospital where an "enlarged heart" was found.

He was admitted to this unit at the age of three months. In the interim several similar attacks of pallor, sweating and unconsciousness had occurred. The child had been increasingly dyspnoeic, and frequent hospitalisation had been necessary. Shortly before admission here, the mother had noted swelling of the eyelids.

Full questioning revealed that a transient episode of pallor and sweating had occurred at the age of two weeks. Family and social history were not contributory.

Examination

Length - 56 cm.
Weight - 4 kgms.
Head - 37 cm.

The child was malnourished and dyspnoeic at rest. The skin showed a greyish cyanosis. The cry was weak. No limb oedema was present though the eyelids were somewhat swollen. The pulses were difficult to feel. The heart was greatly enlarged to the left, with bulging of the left upper chest. No praecordial thrill was felt. A soft systolic murmur was audible near the apex. The liver was enlarged to the level of the umbilicus.

Progress: Digitalis failed to improve the incipient congestive failure. The child died suddenly some three days after admission.

X-ray examination showed the heart to be greatly increased in size; this was principally left ventricular. The lung-fields were slightly plethoric. Fluoroscopy suggested a rather narrow vascular pedicle in the P.A. view. This widened on rotation into the left oblique. Electrocardiography showed a rapid sinus tachycardia and "right ventricular" dominance.

Autopsy

The heart was greatly enlarged. The left ventricle was thickened and somewhat dilated. The aortic valve was thickened and the cusps fused, so that the orifice would admit only a match-head. This stenosis

extended down into the left outflow tract. Moderate hypoplasia of the aorta was present. Small patches of fibrous thickening flecked the endocardium of the left ventricle. Systemic and pulmonary venous return was normal. The ductus had closed, and there were no defects of septation. Microscopy confirmed the diagnosis of fibroelastosis.

Summary of Case 1

This child presented with episodes of 'syncope' comparable with that found in adult cases of aortic stenosis. The heart was greatly enlarged though only a soft bruit was present. The pulses were difficult to feel. The child had cyanosis and early congestive cardiac failure. Autopsy showed aortic and sub-aortic stenosis due to fibro-elastosis.

CASE 2

This infant, the product of a normal gestation was admitted at the age of three weeks. Moderate cyanosis had been noted on the second day of life. This became more obvious on crying. Dyspnoea was noted on the fourth day. She fed well and gained weight, but shortly before admission she developed a cough. This was. followed by swelling of the eyelids, hands and feet.

Examination

The child was relatively well nourished; greyish cyanosis was present and the cry was feeble, with much

dyspnoea. The eyelids, hands, feet, and abdomen were swollen. The apex was greatly displaced to the left. A grade 3 systolic murmur, maximal over the 3rd and 4th inter-spaces was well transmitted to the back. The pulses were difficult to feel. Free fluid was present in the abdomen; an enlarged liver could be felt through this.

X-rays showed a greatly enlarged heart which was ovoid in shape: left ventricular increase was suggested. E.C.G. (limb leads only) showed right axis deviation.

The child died suddenly on the day following admission.

Autopsy

Both ventricles were enlarged, the heart weighing 60 grams. The aortic cusps were short thick pads causing marked stenosis. The mitral valve showed minor changes of the same nature. The left ventricle showed spotty opacities. The ductus was closed and septation was complete.

Microscopy The aortic valve was composed of delicate fibrous tissue. The endothelium was fragmented. The left auricle showed areas of subendocardial connective tissue.

These findings were interpreted as fibro-elastosis.

Summary of Case 2

This three week-old child had been cyanotic and

dyspnoeic since birth. Intractable congestive cardiac failure developed. The heart was greatly enlarged. Autopsy showed fibro-elastosis with stenosis of the aortic valve. The mitral valve was minimally affected.

Discussion

Endocardial fibro-elastosis, or sclerosis may primarily involve the mitral valve, (Maxwell & Young), or the aortic valve as in the cases of Brown already quoted or of Torp (1951). The condition may exist without valvular involvement (Edmonds & Seelye, 1951). The condition carries a poor prognosis though DuShane (1954) considers that the case reported by Sharkey and McGovern, who survived to the age of three years, may be similar to the cases here reviewed. One of his own cases was two and a half years of age at death.

The clinical features in the two cases presented here are of some interest. In case 1, the syncopal episodes closely resembled those reported in adults with the same condition. Congestive cardiac failure was an intractable feature common to both cases. Cyanosis of a peculiar greyish colour occurred in both cases. This has been noted in another case of mitral fibro-elastosis. (Maxwell & Young). The difficulty in palpation of the pulses was a feature in both.

Gross cardiac enlargement occurred in these, as in other reported cases. The electrocardiogram was of very little value in diagnosis. In both cases no feature suggestive of left ventricular involvement was found.

X-ray findings are essentially gross cardiac enlargement - mainly of left ventricular origin. The narrow vascular pedicle in the P.A., with increase on oblique rotation was somewhat suggestive of transportion in case 2. This impression was further strengthened by evidence of pulmonary plethora. It would seem unlikely that these infants are ever suitable cases for surgical interference presenting as they do with intractable congestive failure.

References

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Edmonds, H.W., Seelye, W.B., (1951), Pediatrics, 7, 651.

Maxwell, G.M., Young, W.P., Amer. Heart J. (in the press).

Torp, K.H., (1951), Acta Path. et microbiol. Scandinav., 29, 109.

Section 11

GENERAL SUMMARY

GENERAL SUMMARY

A large number of congenital anomalies of the heart are presented and discussed. All of the cases were within the paediatric age-group, the majority being less than five years of age. The symptoms and signs are discussed in detail, and the results of electro-cardiography and X-ray investigation presented. The results of cardiac catheterization are given in certain cases. The diagnosis was tested by each or all of these methods, and, too often by autopsy. Further proof has accrued since the completion of the thesis and no undue reversal of opinion has ensued.

In the intervening time also, further information concerning the general attitude towards these cases has been obtained. It is essential that each case should be fully investigated at the first appearance of the child in the out-patient department; too often the child is left "until it is bigger", or "until it is in trouble", before every avenue is explored. The author unfortunately shared this attitude, until the frequency of death during the "follow up" period showed how lethal this neglect could be. Potentially curable cases such as atypical patent ductus arteriosus were found at autopsy, because retrograde angiography or cardiac catheterization was not carried out in time.

Similarly operation should not be denied the

youngest of children who have such lesions as tetralogy of Fallot or pulmonary stenosis with a normal aortic root. Such cases too often die while waiting for the "great vessels to increase in size". The indication for operation are the classic ones of paroxysmal dyspnoea, and limitation of effort; to these must be added failure of growth, epitomized by a sinister downward progress of percentiles. These and more subtle signs of "failure to thrive", are best appreciated by those with a paediatric rather than a cardiological training.

Even if mistakes are made, thoracotomy in experienced hands will be safe enough to allow of direct examination of the lesion, if pre-operative assessment is incomplete. Undoubtedly the attendance of personnel with physiological apparatus for the measurement of pressure and oxygen tension will increase the efficiency of the surgeon and may lead to the discovery of better methods of treatment.

So then it is suggested that every child who shows symptoms be considered as potentially operable. Thus <u>all</u> cyanotic cases should have angiocardiography if the diagnosis is not immediately obvious. Equally, cardiac catheterization should be carried out in all acyanotic cases with symptoms unless a "Gibson" murmur, absent femoral pulses, or other undoubted criteria make the

diagnosis reasonably absolute. The latter technique is, as the author has found, perfectly applicable to all cases, except perhaps premature infants - in one case an infant of 4 Kgms. was subjected to this investigation - with the happiest results.

The high morbidity and mortality in these children is a challenge to the therapeutic acumen of the paediatrician, and demand his constant review and supervision of the individual case. Fluoroscopy and interpretation of the electrocardiogram should be within the province of the paediatric physician, and, if the apparatus is available he should be able to turn his hand to cardiac catheterization.

APPENDIX

A note on cardiac catheterization with a table of the formulae used

FORMULAE

1. Cardiac Output = $\frac{O_2 \text{ consumption} \times 100}{\text{Systemic Art } O_2 - \text{PA } O_2 \text{ (Vol\%)}}$

2. Pulm. Blood Flow = $\frac{O_2 \text{ consumption} \times 100}{\text{Pulm. Vein } O_2 - \text{PA } O_2 \text{ (Vol\%)}}$

   Pulm. Vein assumed 95% when unknown.

   Cal of PV O_2 = ((O_2 saturation - .6) x 95%) + 0.2

3. Systemic Blood flow = $\frac{O_2 \text{ consumption} \times 100}{\text{Systemic Art. } O_2 - \text{mixed venous } O_2}$

   Mixed Venous O_2 = $\frac{\text{SVC} + (2 \times \text{IVC})}{3}$ if ASD.

   = $\frac{\text{SVC} + \text{IVC} + \text{all RA}}{\text{No. of samples in numerator}}$ if VSD.

   = $\frac{\text{RA} + \text{Low RV}}{\text{No. of samples in numerator}}$ if PDA or Aortic Window

4. Effective Pulm. Blood Flow = $\frac{O_2 \text{ consumption} \times 100}{\text{Pulm. Vein } O_2 - \text{mixed Venous } O_2}$

5. Shunts

   Overall = Systemic BF - Pulm. BF.

   L-R = Pulm. Blood Flow -effective Pulm. Blood Flow

   R-L = Systemic Blood Flow-effective Pulm. Blood Flow

6. LV Work = $\frac{\text{CO} \times \text{MABP (cm Hg)} \times 13.6}{100{,}000}$ = KG. M/min.

7. RV Work = $\frac{\text{CO} \times \text{MPABP (cm. Hg)} \times 13.6}{100{,}000}$ = Kg. M/min.

8. Pulm. Arteriolar Resist. = $\frac{(\text{MPABP} - \text{MPCP}) \times 1332}{\text{CO} \div 60}$ = dynes/cm^{-5}/sec.

8½. Periph. Resist. = $\frac{\text{Systemic AM} - 0 \text{ (or RA mean)} \times 1332}{\text{CO} \div 60}$ = dynes/cm^{-5}/sec

9. Forward (Stenotic Mitral Valve Area) = $\frac{\text{CO} \div \text{DFP}}{31\sqrt{PC_m - 5}}$

10. Pulm. Value ares (Stenotic) $\frac{\text{CO} \div \text{SEP (Flow/Syst. Sec)}}{-44.5\sqrt{\text{RVsm} - \text{PAsm}}}$ = Cm^2

11. Ductus Arteriosus Area = $\frac{\text{Ductus flow/sec}}{44.5\sqrt{\text{Aortic m} - \text{PA m}}}$ = Cm^2

    Atrial Septal Defect Area = $\frac{\text{ASD flow (cc/sec)}}{44.5\sqrt{\text{LAm} - \text{RAm}}}$ = Cm^2

    V. Septal Defect Area = $\frac{\text{VSD flow (cc/sec)}}{44.5\sqrt{\text{LVm} - \text{RVm}}}$

    LVm = BAsm x $\frac{\text{SEP (sec/beat)}}{\text{Card. cycle (sec/beat)}}$ + PCm x $\frac{\text{DFP (sec/beat)}}{\text{Card. cycle (sec/beat)}}$

A NOTE ON CARDIAC CATHETERIZATION IN THE INFANT AND YOUNG CHILD

This method of investigation differs markedly from that in the adult. Anaesthesia is almost always necessary, though this may be replaced in the co-operative older child by basal narcosis with morphine and scopolamine. Infiltration with local anaesthetics is desirable as a prophylaxis of venous spasm. The seriously ill anoxic patient may be given continuous oxygen. This does not seem to vitiate calculations of the direction of shunt, though, of course, the absolute values must be in doubt.

Below the age of eighteen months, the arm veins are generally too small for the cardiac catheter. Occasionally a No. 5 size may be used in this site, but much damping of pressure and difficulty in drawing blood samples ensues. It is on all counts preferable to use the saphenous or femoral vein. Unfortunately difficulty may occur in entering the pulmonary artery by this route. Certainly only frequent attempts will give success, though it is a useful manoeuvre to advance the catheter tip into the high right ventricle with a stylet in place. This may then be removed, and gentle pulling back and forth with the now more pliant catheter will often advance it into the lung-fields.

Experience has shown that it is often necessary to

assume that an atrial septal defect is present until otherwise proved. One can only be sure of this by frequent probing of the atrial septum. This is conveniently carried out at the end of the investigation, and sufficient pluoroscopy time should be reserved for it, even when checking of the blood samples does not suggest a left to right shunt.

In ventricular septal defect without aortic overriding but with a balanced or reversed shunt, a positive diagnosis sometimes cannot be made. In the presence of pulmonary hypertension, the diagnosis may be suspected by exclusion of an atrial septal defect or patent ductus arteriosus. A true isolated ventricular defect cannot be traversed, as is readily seen from inspection of autopsy specimens.

In the very young child, a substantial volume of blood may have to be removed if oxygen tensions are checked by the Van Slyke method. The amount removed should be recorded, and appropriate replacement with compatible blood carried out at the end of the procedure. Oximetry by the method of Wood, which allows of direct estimation and re-injection will substantially simplify this aspect of the investigation.

In all cases it is necessary to be careful with the amount of radiation given. A fluoroscope with an automatic timer is an essential, and the machine should

be calibrated regularly. It would seem that extensive fluorscopy, angio-cardiography, and cardiac catheterization should be separated by a reasonable time interval. This will avoid the hazard of over-exposure.