CONGENITAL HEART DISEASE AS A CAUSE OF SUDDEN UNEXPECTED DEATH IN CHILDREN UNDER ONE YEAR OF AGE

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There is a large literature on congenital malformations, particularly congenital heart diseases, as witness the most excellent "Atlas of Congenital Heart Disease," by Abbott¹, and the section on congenital heart disease in "Heart Disease" by White². In the older literature the works of Schwalbe³, and Brüning and Schwalbe⁴ remain classics.

The incidence of congenital malformations appears to be quite uniform in the statistics examined from various clinics in this country. This is particularly true of the frequency of congenital heart disease. The variation in number of these cases is manifest by the greater incidence of congenital heart disease in the northern climates as compared with the south¹⁴.

Our attention was directed to the low incidence of congenital heart disease in those dying suddenly without previous medical care. It has been my privilege to investigate and perform autopsies on approximately 750 to 800 cases each year (natural and traumatic deaths), referred to the Coroner’s Office from one district in Chicago.

Approximately 50 per cent of this number were deaths due to supposed natural causes (individuals dying unexpectedly without previously being under a physician’s care) and included infants and children, as well as adults. Sudden death due to congenital heart disease occurs very seldom. In approximately 8500 Coroner’s cases which I have investigated in the past 13 years there were but eight cases of sudden death due to congenital heart disease in children under one year of age. Munck⁵ re-
ported that in the University of Copenhagen in 3,988 Coroner’s autopsies there were 1,092 deaths due to unexpected causes and of this number 8 or 0.7 per cent were due to congenital heart disease. In these eight cases death occurred in the first year of life. In this same material there were 352 unexpected deaths in children during the first year of life which were not due to congenital heart disease.

Pott reported his investigation of 30,000 children under ten years of age; 95 showed evidences of heart disease, but he was unable to determine how many of this number were due to congenital heart disease. He pointed out that it was rather difficult to obtain statistical data concerning congenital heart disease and the frequency of this malady in relationship to sudden death. Berblinger showed that 50 per cent of all children in the first year of life and 33 per cent of older children show evidences of a patent foramen ovale. Recently Potter and Adair made a survey on “Factors Associated with Fetal and Neonatal Deaths” and analyzed 773 such deaths in 17,728 deliveries at the Chicago Lying-In Hospital covering a period of almost seven years. They showed that malformations (apparently all types of malformations) accounted for a remarkable proportion of deaths in full term infants who died in the neonatal period (41.7 per cent of those examined at autopsy). The nature of these various types of malformations is not indicated in their report. In live born infants who died in the neonatal period one of the most important causes of death was malformations (24.5 per cent) while in stillborn fetuses malformations occurred in 12.4 per cent.

It is of further important significance that these authors state that “in only 57 per cent of all dead infants and fetuses examined at autopsy could a definite pathologic state be demonstrated.” This varied from 90 per cent for live born infants and 44 per cent for premature stillborn infants.

A recent report by Murphy on congenital malformations is of profound importance. In his survey in Philadelphia from January 1929, to December 1933, approximately 68 individuals per 10,000 showed gross congenital malformations. He further pointed out that among all deceased live born individuals 54 per
10,000 showed evidences of malformations; among all stillborn individuals 297 per 10,000 possessed congenital malformations. He had further shown that gross congenital malformations as recorded upon death certificates in Philadelphia afflicted approximately one in every 213 individuals born alive. Of the total number of all types of congenital malformations Murphy has tabulated 80 cases in which there was a defect in the cardiovascular system. Of these 34 had a diagnosis of heart disease, 23 had a patent foramen ovale; 7 showed an absence of the interventricular septum, 4 a patent ductus arteriosus, 3 a pulmonary stenosis, 2 an ectopic cordis, 2 a myxedema, 1 a mitral regurgitation, 1 an absence of the left ventricle, 1 an atresia of the right ventricle, 1 a tricuspid insufficiency, and 1 an endocarditis.

Ash, Wolman and Bromer made a clinical and pathological study of 32 cases of congenital cardiac defects in infancy and have correlated the clinical histories as well as the electrocardiographs and X-ray observations made on some of their patients, with the suggestion that they have made an attempt to evaluate the diagnostic features associated with congenital lesions in infancy with the autopsy findings.

MATERIAL STUDIED

The material here reported is taken from three sources; the Cook County Hospital, and the Research & Educational Hospitals (both of these institutions have obstetrical and pediatric departments), and the Cook County Coroner's Office.

In the Cook County Hospital* during the years 1929 through 1939, 12,837 autopsies were performed; this includes, infants, children, and adults. Of this number there were 78 cases or 0.607 per cent of congenital heart disease in children under one year of age. The sexes were equally divided, 39 males and 39 females. The incidence of congenital heart disease was increased in the whites, 51 cases or 65.3 per cent as compared with the colored, 27 cases or 34.6 per cent. Thirty-five or 44.8 per cent of the 78 cases were diagnosed clinically as having had a congenital cardiac defect, whereas, in 43 cases or 55.1 per cent there was no previous history or clinical evidence of congenital heart or blood vessel disease.

* This data was supplied by Dr. J. Kirshbaum with the assistance of Mr. S. J. Kaplan, from the department of pathology, Cook County Hospital.
In 1,921 autopsies in the Research & Educational Hospitals from the years 1927 through 1939 number 23 or 0.11 per cent showed gross and definite evidence of congenital heart disease. The ratio of males to females was 13 to 10, and white 18 to colored 5.

Of 8,500 cases personally investigated in my own district as a coroner's physician in the past thirteen years, there were 50 per cent or 4,250 cases of sudden or unexpected death; in other words these individuals died without having been previously ill, or without having being under a physician's care. This group includes infants and children, as well as adults. In this series I have performed autopsies on 8 children under one year of age in which I have found congenital defects of the heart or blood vessels which were directly re-

![Fig. 1. Patent Ductus Botalli in a Six Weeks Old White Male](https://academic.oup.com/ajcp/article-abstract/11/10/741/1757018/745)

FIG. 1. PATENT DUCTUS BOTALLI IN A SIX WEEKS OLD WHITE MALE

sponsible for the unexpected death. The parents were asked if the children had been sick at any previous time, or if they had shown any evidence of cyanosis which would have prompted them to consult a physician. The answer invariably was "No." Some of the mothers had taken their children to the Infant Welfare Station for examination and were not warned by the physician of any evidence of illness. It is known that many of the congenital defects of the heart do not show any clinical alterations.

My series of Coroner's cases includes the following:

2 cases of cor bovinum with congenital pulmonary stenosis and marked hypertrophy and dilatation of both auricles and ventricles. The first was a white male 5 weeks of age found dead in bed by its mother. The second case
was a 9 month old white female also found dead in bed. Parents of both children stated that the infants were never sick before and when seen by the doctor for a routine monthly examination were told the children were in good health.

1 case of idiopathic hypertrophy of the right and left ventricles. This case was in a three month old white male found dead in bed.

The heart in congenital hypertrophy (idiopathic or not) is frequently two to three times the normal weight (75 grams instead of 25 grams at the age of 4 months) and may also be considerably dilated (White²).

Two cases of patent foramen ovale and patent ductus Botalli, one in a five month old white male, the second case in a six week old white male. Autopsy findings in both children did not show any gross pathological changes other than the congenital anomaly of the heart and vessel.

Herxheimer (quoted by W. Berblinger) has shown that the foramen ovale is open, partially or completely, in 50 per cent of all children under one year of age and in 33 per cent of older children and adults. According to White², patency of the foramen ovale is of the least importance and of greatest frequency of all congenital cardiac abnormalities. He reports a series of 500 hearts (250 white and 250 negro subjects) in whom probe patency of the foramen ovale was found in 85 cases (17 per cent) while in only 2 cases (0.4 per cent) the valve of the foramen ovale actually failed completely to cover over the foramen (Seib, 1934). In Abbott’s series of 40 cases the duration of life or primary wide patency of the foramen ovale varied from 3 months to 70 years, averaging 39 years².

White² has reported that patency of the ductus arteriosus of Botalli may be regarded as a congenital anomaly if it is found later than 3 months after birth. It is one of the commonest of all congenital cardio-vascular defects, ranking third (150 cases) in incidence after interauricular and interventricular septal defects in Abbott’s series of 1,000 cases. It is, however, surprising to find how often physicians are either unaware of the existence of this congenital anomaly or miss it by failure to heed its signs. Patent ductus Botalli is found more often in the female, the sex ratio being 2 to 1 (Abbott).

One case of patent interventricular septal defect and interauricular septal defect in a white female five weeks of age.

In later development of the embryo defects may occur in the
septum which may result, either in a patent interventricular septum which is seen as a patent foramen ovale, or a persistent opening in the auricles. When the interference involves the interventricular septum this may result in a patent interventricular ostium. At this stage of embryo development there may also be a disturbance in the common truncus arteriosus which may result in various types of malformation such as transposition of the great vessels, malposition of the aortic septum in relationship to the interventricular septum, etc.

One case of congenital idiopathic hypertrophy and dilatation of the right and left ventricles with a patent foramen ovale. This occurred in a three month old white male.

One case of tetralogy of Fallot. This involved a stenosis of the pulmonary artery, interventricular septal defect, deviation origin of the aorta to the right, and a concentric hypertrophy of the right ventricle.
A white female 10½ months of age was seen in the dispensary as well as in the Childrens Welfare Department for routine examination. There were no symptoms or anything unusual noted by the mother except that the physician heard harsh heart tones and suspected a congenital heart disease. The child was apparently in good health until the day of admission to the hospital when the mother was awakened in the early morning by the child's crying. The patient appeared to have difficulty in breathing and the skin was pale but not blue. The temperature was subnormal as reported by the mother and the child was immediately taken to the hospital. On admission the child was in a moribund condition and a physical examination was impossible. Death occurred within a few minutes after admission to the hospital.

The clinical impression was congenital heart disease, foreign body aspiration, or laryngeal diphtheria. Post mortem cultures were made from the throat and revealed no Kleb-Loefflers bacilli, but showed a few cocci.

In Abbott's series the tetralogy of Fallot was represented in 77 per cent of the 110 cases of pulmonary stenosis and in 66 per cent of the 40 cases of atresia classed as the primary lesion in her series of 1,000 cases analyzed. Abbott further pointed out that despite the high degree of oxygen unsaturation which

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**Fig. 3. Tetralogy of Fallot in a 10½ Month White Female**

Black marker A shows stenosis of the pulmonary artery, and B patent interventricular septal defect.
they invariably present, they may attain adult life, the maximum approximately 25 years and the average in 83 cases being 12 1/2 years.

The whole appearance is highly suggestive of the relationships that would result from the uncovering of the right reptilian aorta and obliteration of the left in the delayed torsion of Spitzer's theory (his types 1 and 2 of transposition).*

All of these cases were under one year of age and the stories more or less have been the same in that the mothers found the child dead in bed. None showed any evidence of congenital malformation of any of the internal viscera nor of the extremities. These cases were reported merely to indicate the possibility that there may be a greater incidence of congenital heart disease if more of these cases of unexpected deaths in infants and children were autopsied.

DISCUSSION

The exact etiology of congenital malformations, particularly that involving the heart is not known. It is generally agreed that congenital abnormalities are inherited, but there is a great deal of evidence to show that environment also is an important factor. As to heredity, Mall has shown that inherited tendencies are contained within the egg substance itself, and the external conditions which surround and act upon this substance. Environment of the ovum may be sufficiently modified experimentally as to effect its growth was demonstrated by Stockard, Bagg, and Murphy.

White is of the opinion that the maldevelopment in most hearts has been variously ascribed to defects in the germ cells and to adverse influences coming from the maternal organism during pregnancy; original or very early developmental germ cell defects are apparently responsible for the majority of cases.

If this is logical, and there is every indication to believe that the evidence is correct, let us briefly analyse the factors disturbing

* Spitzer's theory, ascribes such anomalies to the arrest or delay of the clockwise torsion that normally takes place in the growth of the primitive embryonic heart between its fixed arterial and venous ends during the process of septation, thus leading to an apparently counter clockwise shunting of the part with resultant reopening of the channel of the reptilian right aorta and obliteration of the left ventricular vessel. For a more detailed discussion and review of Spitzer's Theory, the reader is referred to the article by Harris and Farber (Archives of Pathology, 28-427, 1939) on Transposition of the Great Cardiac Vessels, with Special Reference to the Phylogenetic Theory of Spitzer.
to the organism as a whole (the mother, as in this case in question), as well as the individual cell or cells, as in the ovum.

In a recent report Murphy analyzed the records in Philadelphia of 826 families in which information was available and found that approximately $\frac{1}{3}$ of the offsprings exhibited gross congenital malformations, that approximately 77 per cent of the defective individuals exhibited malformations which affected only $\frac{1}{3}$ of the body, and that gross congenital malformations as recorded upon death certificates afflicted approximately one in every 213 individuals who are born alive. This author reports that in Philadelphia he has not observed any significant seasonal incidence of the conception of congenital malformed individuals. In 935 cases studied, 80 or 8.5 per cent showed cardiovascular deformities. He has observed that there is a greater frequency of conception of malformed individuals in the summer months (June and July), and of normal individuals in the spring and fall months, and concludes that there is no correlation of conception rate of defective persons with the rate of change of barometric pressures. The seasonal trend in the conception of malformations is of interest and the effect of meteorologic changes will be briefly reviewed here.

In the Chicago region (and these findings are in contrast to the observations made by Murphy in Philadelphia) there are distinctly more conceptions of malformed infants in the months of March and April (120 per cent of the expectancy) as contrasted to the small number conceived during the months of July, August, and September (Petersen). Throughout the spring months there is a greater variability in barometric pressures than during the summer season. The analysis of the conception dates of the seventy-eight cases of congenital heart disease in the Cook County Hospital series, and the twenty-three cases in the Research and Educational Hospital series, and the eight deaths referred to the Coroner's office, agree with the above observation. What is the probable explanation for the effect of meteorologic alterations on the incidence of malformations? The explanation may be sought in differences in the meteorologic stability and instability and its reflection in the autonomic balance of the maternal organism.
This is strikingly illustrated in the greater incidence of congenital malformations in the negro as he moves northward\textsuperscript{14}. In our own records, for example, the incidence is equally divided between the white and colored.

Petersen\textsuperscript{14} has shown that there are differences in physiologic processes in the normal and abnormal individuals that occur as a distinct rhythm and react to meteorologic changes. These can be measured by the fluctuations in the blood pH and oxidation-reduction potentials. His studies have demonstrated that, largely conditioned by cyclonic circulation of the atmosphere, definite periods of increased oxidation alternate with definite periods of enhanced reduction, definite periods of vascular spasm with vascular dilatation, and definite periods of a relative alkalosis with a relative acidosis. From these studies it would seem to be that in the late winter and spring the protoplasm is distinctly unstable, and that the organism is exhausted, more acid, and the cells are more permeable and more irritable. In the fall the cells are less irritable and less permeable, the organism is more stable, and the buffering more adequate. It is obvious, therefore, that interference with normal cell growth will be greater in the spring than in the fall\textsuperscript{14a}.

Keibel and Mall\textsuperscript{16} observed that malformations are dependent on the change in the environment which has effected the metabolism of the egg. It has also been observed that the more severe malformations result from disturbances in the earliest stages of segmentation; malformations of the extremities may occur later and at times from adventitious causes. It is in the earliest phases that changes in the temperature and barometric pressure will be effective in the disturbances of development.

In discussing the significance of the conditional variability of the uterus and ovaries Petersen\textsuperscript{14} has shown that the unstable female is more apt to produce an unusual number of variants; and that the pregnant female will be particularly susceptible to intoxication due to the effect of spasm and anoxemia at the surface of the placental structures. There may also be a modification in the fetus both early as well as late in its development, and finally that modification of the unfertilized ovum by the meta-
bolic status of the ovarian or tubal environment may occur. With
these alterations, the genetic organization of developmental
trends may be influenced as much as the quality of the chemical
structure and the chemical trends of the cytoplasm of the ovum.

In studying the effect of spasm (anoxia) on the rapidly de-
veloping embryo Petersen further states that the anoxemia may
be so severe that the disturbance of normal growth occurs, leading
to injury to the product of gestation or malformation. That
this happens is evidenced by the fact that vascular spasm occurs
with greater frequency the more often the passage of atmospheric
fronts.

Statistical data indicates that the periods of the year showing
the lowest conception rate correspond to the period of greatest
barometric variability in the north. This means that either
there is a greater destruction of the product of conception in the
period of meteorological disturbance, or that the chances for fer-
tilization are lessened.

Because of the numerous evidences recorded in literature by
many investigators both here and abroad, that environment and
physical factors might influence the development of the fetus as
a whole, it might be reasonable to follow that injury to individual
organs in like manner might produce malformations characte-
ristic for these organs. The seat for the unfertilized ovum will
similarly reflect the general status, such as chemical and hormonal
imbalance as may be reflected in the female organism as a whole.

Meteorological conditions existing in the region of the storm
track may be one of the factors in causing a disturbance in the
development of the ovum with the resultant disturbance in the
segmental changes which occurs in the development of the fetus.
This is obvious when one compares the high incidence of con-
genital malformations at large in the Northern States as com-
pared with the Southern States. Due to the fact that the exact
etiology of congenital cardiac defects is not known, we wish to
point out that meteorological alterations may well be included
as a probable cause for the disturbances in the development of
the ovum, and the resultant congenital segmental maldevel-
opment of the fetus. Furthermore, since the high incidence of con-
genital maladies in general is greater in the Northern States than in the Southern States this hypothesis seems more reasonable.

SUMMARY

1. In a series of 12,837 autopsies performed at the Cook County Hospital 78 cases or 0.607 per cent, and in 1,921 autopsies performed at the Research and Educational Hospital 23 or 0.11 per cent, showed evidence of congenital heart disease. All of these children were under one year of age.

2. In a series of 8,500 cases investigated for the Coroner’s office of Cook County, there were eight which showed gross evidence of congenital heart disease, and these children under one year of age died suddenly and were never previously ill, or under a physician’s care.

3. In the text is a discussion of the probable etiologic factors including meteorological alterations which may play a role in congenital malformations of the heart.

REFERENCES

(6) Pott: Quoted by Herzheimer in Schwalbe Die Morphologie der Missbildungen, p. 343.
(10) Ash, R., Wolman, I. J., and Bromer, R. S.: Diagnosis of congenital cardiac defects in infancy; a study of thirty-two cases with necropsies. 58: 8, 1939.
(12) Mall, F. P.: See Keibel & Mall.
(13) Stockard, Bagg, and Murphy: Quoted by Murphy.


