ECG in the Diagnostics of Atrial Septal Defect

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The diagnostics of congenital heart defects has made notable progress in recent years. The clinical pattern, the radiological and electrocardiographic features of frequently occurring cardiac diseases are sufficiently known to warrant a reliable diagnosis in typical cases. Clinical symptoms, X-ray and ECG tracings usually suffice to recognize atrial septal defect. Clinical and radiographical examinations are in this respect of more help than the ECG. Yet, the ECG is more useful for the differentiation of the two principal types of the atrial septal defect than are the clinical or radiological findings.

Most of the reports in the literature deal with adult patients and comparatively few with the atrial septal defect of children [10, 18, 19, 41]. It seemed therefore justified to analyse the ECG records of our Department.

The complicated development of the interatrial septum greatly favours the arisal of various defects [15, 20, 25]. These defects belong to two main types. Persistent ostium secundum, due to developmental disorders of the septum secundum, constitutes the more frequent type. According to its location it may be of (i) superior caval or sinus venosus type; (ii) central type; (iii) inferior caval type. These subtypes occur as a rule separately, but are often accompanied by anomalies of pulmonary venous drainage.

Persistent ostium primum caused by disturbances in the fusion of the dorsal and ventral endocardial cushions, may appear in various forms known under the collective term endocardial cushion defect [44]. Faulty union of the endocardial cushions may give rise to numerous disturbances. At one extreme lies the persistent ostium primum which is usually accompanied by a cleft or other malformation of the mitral or tricuspid valves (partial form). The opposite extreme is represented by the persistence of the common atrioventricular canal when there is but a single orifice between the ventricles and the two atria. The opening extends upward to the patent ostium primum, downward to the highly placed ventricular septal defect (total form of endocardial cushion defect, termed earlier peristent common atrioventricular ostium or persistent common atrioventricular canal). Between these two extremes there are transitional forms of endocardial cushion defect [42]. The term endocardial cushion-defect syndrome has been suggested by certain authors [2, 25] for all these manifestations.

On the basis of clinical symptoms or the evidence of ECG tracings it is not possible to distinguish between the individual forms within the ostium primum and the ostium secundum group. This is, however, irrelevant from the surgical point of view. A more detailed knowledge has only recently been gained in this respect on the evidence of observations made on operated patients.

Apart from clinical symptoms, it is the ECG tracings which are of decisive diagnostic value for the differentiation of the two main types. While defects of the secundum type can be repaired surgically in hypothermia, the correction of the defects of the ostium primum type is a more difficult task, feasible only with extracorporeal circulation.

Earlier reports dealt with the clinical symptoms and the electrocardiographic manifestations of the secundum type of defects only [4, 17, etc.]; later, when catheterization began to yield data concerning haemodynamic conditions, these were co-ordinated with the ECG records [3, 7, 40, 42]. The rising frequency of cardiac operations has directed interest to the postoperative changes and the normalization of the ECG tracings [8, 16, 33]. Recent publications devote much attention to the description and differentiation of the various and surgically different types of atrial septal defects [5, 12, 15, 31, 35]. In addition, the importance of electrocardiographic examinations, that of vectocardiography has been emphasized by several authors [1, 11, 22, 28].

Material and Method

Eighty-four cases of atrial septal defect have been analysed in this study. Clinical symptoms and the radiograph were indicative of the secundum type in 68 cases, the primum type in 12 cases, while 4 cases were atypical secundum defects. The diagnosis was verified by catheterization in 30, at surgery in 21, and at autopsy in 7 cases.

Apart from the standard leads, unipolar limb leads (Goldberger) and also 7 precordial ($V_{R3} - V_6$) leads were employed. The shape and course of frontal vector loops, constructed from synchronously formed standard leads, were analyzed in all cases of the ostium primum type as also in all cases where the ECG tracings were atypical or dubious.

Atrial septal defects associated with pulmonary stenosis (Fallot's trilogy) or mitral stenosis (Lutembacher's syndrome) are not included in the present material.

The patients ranged in age from 8 months to 15 years, with an average of 7.2 years. (The material includes only one 21 year old patient who had the primum type of defect and was operated upon.) The ratio of males and females was 35 : 49, i.e. 42 and 58 per cent, respectively, a proportion in agreement with the generally known predominance of female patients.

Morphology of the Ostium Secundum Type of Atrial Septal Defect

According to the size of the defect, a larger or smaller volume of blood passes through the septal opening from the left atrium of higher pressure to the right atrium of lower pressure. This induces a dilatation and hypertrophy of the latter. The right ventricle, too, receives a larger quantity of blood and becomes likewise dilated and hypertrophic, whereas the left ventricle has no overwork to perform. Long duration of the defect may induce changes in the pulmonary vessels and results in pulmonary hypertension which aggravates the hypertrophy of the right ventricle. The overwork and the hypertrophy of the right chambers manifest themselves in the ECG.

Electrocardiographic Symptoms of Right Atrial Hypertrophy

The P wave is tall and peaked in the leads II, III and aVF. Pathologic changes in the P wave, caused by atrial septal defect, were observed by Sodi Pallares and Marsico [36] in 38 per cent, by Kjellberg [25*a*] in 30 per cent, and by Blondeau et al. [7] in about 16 per cent of the observed cases. Sanchez et al. [34*a*] described the peculiar course of the P wave, characterized by prolongation and by the slow inscription of the ascending limb. While Zuckermann's [45] P-congenitale, i.e. a tall and peaked P wave with a steep ascending limb, is suggestive of a systolic overload of the right atrium, the P wave as described by the said author indicates its diastolic overwork. The most characteristic feature is, thus, the slow and prolonged upstroke of the P wave which was observed by Sanchez et al. in 50 per cent of their 122 cases. A broad notched P wave, characteristic of left atrial enlargement, was observed by Sodi-Pallares [37] in certain cases: it indicated increased pressure in the left atrium, whereas a diphasic P wave in the V_1 suggested right atrial dilatation.

The maximum amplitude of P_{II} in childhood is 2.5 mm, and its duration 0.08 sec.

The P_{II} was taller and more peaked than the normal in 30 (44 per cent) of our cases. The amplitude was 3 mm in 26; 4 mm in 2, and 5 mm in 2 cases. In the aVF the P wave showed an abnormal height in 3 cases only, while the aVR lead in which the P wave reached an amplitude of 3 mm in 13 instances, proved to be of higher diagnostic value. Of the chest leads, V_2 was found to be the most useful; right atrial hypertrophy was indicated by a 3 mm P in 21, one of 4 mm in 6, and of 6 mm in 2 cases. The P wave in the V_1 lead suggested right atrial hypertrophy less frequently, while a higher P in V_{R3} was exceptional.

Standard lead II and chest lead V_2 proved, thus, the most useful for the diagnosis of right atrial hypertrophy, since a tall P wave occurred in 44 per cent. Changes in the form of the P wave which cannot be as easily judged were observed with almost the same frequency. Broad, slowly rising, sometimes slightly bifid P_{II} was observed in 32 cases (47 per cent), and symmetrical peaked P wave in 30 instances (44 per cent).

The electrical axis of the P wave

TABLE I

Incidence of tall P waves

Amplitude of P wave	Lead II	Leads II–III	aVR	aVF	V_{3R}	V_1	V_2
3 mm	26	4	13	3	2	11	22
4 mm	2	—	—	—	1	2	6
5 mm	2	—	—	—	—	1	2

(P_a) showed — in accordance with literary data — a deviation to the right in more than two thirds of the cases, a phenomenon likewise indicative of right atrial hypertrophy.

Increased voltage and changes in the form of the P wave, as also the right shift of the P axis are, thus, fairly frequent (91 per cent), but these characteristic features are not pathognomonic, although they belong to the typical ECG pattern.

Disturbances of stimulus formation did not occur in the examined material. We found a sinus rhythm in all cases; atrial fibrillation, a frequent phenomenon in adults with atrial septal defect was not observed in our patients.

It was in 6 cases (9 per cent) that a prolongation of the PQ interval (0.18 sec or more) indicated a mild disturbance of conduction. Lengthening of the interval is more frequent in materials which include adults. Thus, LEPESCHKIN [27] found it in 37, BEDFORD [4] in 27, and HUMBLET [24] in 25 per cent of their cases. Prolongation of the PQ interval is less frequent in children than in adults with atrial septal defect. Of all the congenital heart diseases it is in atrial septal defect that a lengthening of the PQ-interval is most frequent.

Right ventricular hypertrophy causes in the standard leads right deviation of the main electrical axis. It was between 90° and 119° in the majority of our cases; there were also cases with axes between 60° and 89°. Extreme right deviations were infrequent.

A shift to the right of the mean electric axis is, thus, a typical pattern of right ventricular hypertrophy.

The QRS complex was nearly always prolonged. (It was measured both in lead II and lead V_1. The values were mostly identical. The higher value was accepted in cases of discrepancy.)

A normal value of 0.06 sec occurred

TABLE II

Electrical axis of the P wave

P_a	0	30	45	50	60	71	76	Total
No. of cases	2	10	1	9	28	16	2	68

TABLE III

Values of the electric mean axis (QRS_a)

QRSa	60°—89°	90°—119°	120°—149°	150°—180°	Total
Number of cases	16	42	5	5	68
Per cent	24	62	7	7	100

in 5 cases only, and a slight lengthening was likewise infrequent (10 cases), while values of and above 0.08 sec constituted four fifths of the cases.

In the standard leads, the QRS complex presented in 48 cases the configuration $S_I - Q_{III}$, i.e. the pattern of right axis deviation. The pattern $S_I - S_{II} - S_{III}$ was less frequent (in 7 cases).

TABLE V

Voltages of R aVR

R aVR (mm)	4	5	6	7	8	10	12	Total
No. of cases	12	4	8	4	4	2	1	35

contributes to the increase of voltage due to right ventricular hypertrophy. Table V shows that amplitudes exceeding 10 mm, a sign of advanced hypertrophy, were exceptional. The ECG pattern of right ventricular hypertrophy can best be studied in the right chest leads V_{3R}, V_1 and V_2. A tall R, a depressed S, and a delayed inscription of the ascending limb of the R wave (intrinsic deflection) can be

TABLE IV

Duration of the QRS complex

Duration of QRS (sec)	0.06	0.07	0.08	0.09	0.10	0.11	0.12	Total
No. of cases	5	10	24	13	14	1	1	68
Per cent	7	14	35	20	21	1.5	1.5	100

Thus, the ventricular complexes in the standard leads showed the pattern $S_I - Q_{III}$, i.e. that of right axis deviation and intraventricular conduction defect, phenomena characteristic of a mild hypertrophy and dilatation of the right ventricle.

The position of the heart was vertical in unipolar limb leads, while, as a sign of hypertrophy, increased R voltage was frequent in the aVR lead.

The R aVR wave was taller than 3 mm in 35 cases (about 50 per cent). A clockwise rotation around the longitudinal axis of the heart probably

seen. Table VI shows that in the right chest leads the R wave was comparatively high in 75 per cent of our cases, while values above 20 mm, indicative of pronounced hypertrophy, occurred but seldom.

A further sign of right ventricular

TABLE VI

Amplitudes of the R waves in leads V_{3R} and V_1

Voltage (mm)	8	10	15—20	above	Total
No. of cases	23	20	4	4	51

TABLE VII

Configuration of QRS complex in right chest leads

Pattern	rS	rsr'	rsR', rR's	rR'	Total
No. of cases	5	12	39	12	68
Per cent	7	18	57	18	100

hypertrophy consists in a delay of the R peak. Since the atrial septal defect is frequently accompanied by disturbed right intraventricular conduction, the delay is even more pronounced: the onset of the intrinsic deflection amounted to more than 0.04 sec in 48 cases (70 per cent).

The pattern presented by the QRS complex in the right chest leads was, instead of the usual rS, in most cases rsr′, rsR′, or R′.

Table VII shows that, while the patterns rsr′ and rR′ were fairly frequent (12 cases each), the configuration rsR′ (or the equivalent pattern rR′s) appeared to be the most characteristic sign of atrial septal defect, since it was observed in 39 cases (57 per cent). The normal rS pattern occurred in 7 per cent only.

Right intraventricular conduction was, thus, delayed in 75 per cent of the cases. The delay was mostly slight, with a QRS duration below 0.10 sec (incomplete right bundle branch block); a more pronounced delay (of or above 0.10 sec) occurred only in 16 cases, i.e. in 24 per cent. These figures are in fair agreement with literary data. BARBER [3] observed delayed conduction in 95, STORSTEIN and EFSKIND [38] in 74 per cent of their cases.

The pattern rsR′ on the right side of the chest, instead of the usual rS configuration, is highly characteristic of atrial septal defect.

The pattern rsr′ was originally interpreted as a sign of disturbed conduction, and this is why it is still called right bundle branch block. It was, however, subsequently found that this pattern appeared also in perfectly normal patients where there was no suspicion of a conduction disturbance. KOSSMANN et al. [26], PRYOR et al. [34] and other authors demonstrated that the pattern rsr′ — the so-called incomplete right bundle branch block — was a physiological phenomenon, very frequent in children, less frequent in adults, and that it was due to a delayed activation of the supraventricular crista, the last area of the right ventricle to be excited.

The rsR′ pattern, as seen in right chest leads in atrial septal defect, differs from the configuration under discussion in that the second R wave is notably higher than the first and is, thus, suggestive of right ventricular hypertrophy.

Studying cardiac diseases which involve overwork of the right heart, CABRERA and MONROY [14] found that when an overloading of the right ventricle was associated with increased right intraventricular pressure, a high R voltage with ST—T alterations could be observed in the precordial leads. In cases of diastolic overload, increased R voltage — indicative of right ventricular hypertrophy — was accompanied by incomplete right bundle branch block, i.e. a broadening of the QRS complex. The said authors regarded the pattern, observed in cases of atrial septal defect, as typical for the overloading of the right ventricle. The rsR′ pattern of incomplete bundle branch block, when the second R wave is taller than 8 mm, indicates, according to Blount et al. [9], a hypertrophy of the right ventricular outflow tract, i.e. that of the supraventricular crista. The pattern rR′ or solitary R, observed in another group of right ventricular hypertrophy, indicates hypertrophy of the free wall of the right ventricle or that of the entire ventricle.

The most typical configuration of atrial septal defect, i.e. the pattern rsR′, means, thus, a local hypertrophy of the supraventricular crista. The right ventricle contracts along its longitudinal axis during systole so that the load of the increased volume of blood has to be borne mainly by the basal portion, the outflow tract, the supraventricular crista, which results in a dilatation and hypertrophy of the affected ventricle. In addition, the number of Purkinje fibres is considerably less in the basal portion than elsewhere and there conduction is slower; these two factors cause the spread of the excitation to be delayed [32]. Pulmonary hypertension and the consequential hypertrophy of the entire ventricle, developing in the further course of this process, manifest themselves in the ECG tracings through a solitary R wave or the pattern rR′.

It is, thus actually the basal portion of the right ventricle which becomes hypertrophic in atrial septal defect, while the free wall of the ventricle is dilated rather than hypertrophied, a phenomenon repeatedly observed at surgery [28*a*]. The pattern rsR′ is due to that the activation of the basal portion of the right ventricle is delayed because of the local hypertrophy and ventricular dilatation. This is substantiated by the fact that the incomplete bundle branch block turns into a complete one if the dilatation increases. Pulmonary hypertension and total right ventricular hypertrophy, arising if the anomaly is persistent, cause the QRS complex to become slender and the pattern rsR′ to be replaced by a solitary R of high voltage. The bundle branch block subsides after successful surgical intervention.

It follows from the foregoing that the configuration rsR′, observable in cases of atrial septal defect, is a special transient manifestation of right ventricular hypertrophy [30, 43].

Clockwise rotation around the longitudinal axis of the heart gives rise to the patterns Rs and rs in left chest leads (V_5—V_6) if the hypertrophy of the right ventricle is pronounced. The S wave is equal or higher than the R wave. We saw this pattern, indicative of the serious hypertrophy of the entire right heart, in 4 cases only. The preponderance of the left ventricle, as shown by the patterns Rs and qRS, remained un-

TABLE VIII

The QRS complex in leads V_5 and V_6

QRS pattern	rS	RS	Rs	qRS	qRs	Total
No. of cases	4	11	22	5	26	68

changed in the majority of the cases.

The R wave in the leads V_5 and V_6 remained in all cases below 26 mm, i.e. within normal limits.

A simultaneous inspection of the right and left patterns reveals that there are two frequent combinations in atrial septal defect. In the minority of the cases, the right-side patterns rsr′ or rR′ is associated with the left-side pattern qRs. In the majority, the pattern rsR′ of the right side is accompanied by the pattern Rs on the left side (without q, a sign of moderate clockwise rotation).

When analyzing the QRS patterns obtained in precordial leads, one should bear in mind that right ventricular hypertrophy accompanied by a tall R wave or qRs complex may mean the presence of a combined hypertrophy, and that it is precisely the exclusion of the latter which is most important for the differentiation between ventricular and atrial septal defect. Haemodynamic conditions in atrial septal defect are not conducive to the development of left ventricular hypertrophy, nor do post-mortem examinations reveal such a change. The probable explanation of the left-side pattern indicative of moderate hypertrophy in the right and normal conditions in the left ventricle is that the free wall of the right ventricle is just distended and the hypertrophy of this chamber is restricted to the outflow tract, so that the normal ratio between the walls of the two ventricles remains unchanged.

A survey of the catheterized cases shows that the configurations rsR′, V_1 and RS V_6 mostly occurred when the shunt was pronounced, while the patterns rR′ V_1 (rsr′ V_1) and qRs V_6 were mostly seen in connection with less marked shunts. There seemed to exist a direct correlation between the magnitude of the shunt and the delay of the intrinsic deflection. Literary data confirm the existence of this correlation [24, 32, 43].

A repolarization disturbance was infrequent. Only in 5 cases of pronounced defect did we find an ST—T alteration which may possibly have been due to preceding acute infectious diseases. It is certain that deviations of the S—T segment are not a characteristic feature of atrial septal defect.

The electrical axis of the T wave was, as a rule, in mid position, a negative T_{III} occurred in 8 cases only. Still, the difference between the angles QRSα and Tα did in no case exceed 70° and was, thus, not pathologic.

The T wave did in no case exceed 6 mm in standard leads and 4 mm in unipolar limb leads; amplitudes

TABLE IX

Electrical axis of the T wave

Tα	71°	60°	50°	45°	30°	11°	0°	−30°	Total
No. of cases	7	18	18	10	10	2	2	1	68

above 8 mm were rare also in precordial leads. As is usual in children, the T wave was mostly negative in right chest leads; it was positive in 4 cases, a phenomenon whose cause remained unexplained. Neither the clinical picture nor the catheterization furnished evidence of pulmonary hypertension.

The frontal vector loops, constructed from synchronous standard leads, showed a clockwise rotation in all cases, and their major portion was inscribed below the zero point. Although, in cases of incomplete and complete right bundle branch block, the shape of the loop was irregular and showed sometimes a figure-of-eight pattern, the rotation of the initial forces was invariably clockwise.

The characteristic ECG pattern of atrial septal defects of the ostium secundum type is a tall P wave, mostly in the leads II, aVR and V_2; the angle Pα shows a slight shift to the right; the dilatation and hypertrophy of the right atrium give often rise to P alteration (peaked, symmetrical or broad, slowly ascending P waves).

The ventricular complexes reveal a right axis deviation in standard leads, and a high voltage of R aVR, and a vertical position of the heart in unipolar limb leads. The pattern of incomplete right bundle branch block and moderate right ventricular hypertrophy was observed in right chest leads; we saw the peculiar configuration rsR′ in the majority of the cases, while the pattern in left chest leads was RS or qRs.

The ECG tracings obtained from the right side of the chest suggested a diastolic overload of the right ventricle and the local hypertrophy of the right ventricular outflow tract, whereas the configuration obtained from the left side indicated an essentially unchanged ratio of the two ventricles.

Changes in the form and amplitude of the P wave are somewhat more frequent in children than in adults, while no atrial fibrillation was observed in any of our cases. Residual preponderance of the right ventricle is a physiological phenomenon in childhood, and we saw, accordingly, the pattern rR′ more frequently in right chest leads.

A normal ECG pattern does not exclude the possibility of a moderate degree of atrial septal defect. The peculiar precordial ECG pattern, as described in the foregoing, together with the deviations of the atrial wave, the electrical axis and the aVR were nevertheless observed in most cases, and they are so characteristic of the atrial septal defect as to allow a prompt and correct diagnosis. Yet, it must be borne in mind that the said configuration is neither pathognomonic nor invariable — it was present in two-thirds of our cases only.

Morphology of the Ostium Primum Type of Atrial Septal Defect

This type of defect (also known as endocardial cushion defect syndrome) was found in 12 of our cases: it was verified at autopsy in 5 infants, at surgery in 3 cases, by catheterization in 1 case, and was clinically typical in 3 cases.

Provided the defect is not complicated, this type does not essentially differ from the secundum type of defect as far as haemodynamical conditions are concerned. Yet, owing to the larger defect, the clinical picture is usually more serious in this type. The right atrium and the right ventricle are overloaded, and the ECG tracings show the corresponding alterations of the atrial and ventricular waves. This notwithstanding, the ECG tracings obtained in limb leads are quite different from the corresponding tracings of the secundum type: there is invariably a left axis deviation in the standard leads, and the position of the heart is always horizontal in unipolar limb leads. On the other hand, the pattern obtained in precordial leads is the characteristic one of right ventricular hypertrophy also in this type of defect.

A tall P wave was more frequent than in the secundum type. In lead II, the P wave reached 3 mm in 6 cases, 4 mm in one case; in leads aVR and V_1 it reached 3 mm in 4 cases; in lead V_2 it was 3 mm in 4 cases and 4 mm in 2 cases. The electrical axis of the P wave was usually in mid-position; it was between $+30°$ and $+60°$ in 9 cases.

Prolongation of the P—Q interval was considerably more frequent in the primum type (4 cases out of a total of 12, i.e. 33 per cent against 9 per cent in the secundum type of the defect).

TABLE X

Values of the main electric axis ($QRS\alpha$)

$QRS\alpha$	$-1°—30°$	$-31°—60°$	$-61°—90°$	Total
Number of cases	1	6	5	12

No disturbances of rhythm were observed.

The main electric axis showed a shift to the left in all of the 12 cases, a phenomenon which was especially striking at the post-mortem examination of infants. The left axis deviation was pronounced (the axis was usually between $-30°$ and $-90°$).

As a rule, the QRS complex displayed the configuration $q_I S_I S_{II} S_{III}$; the pattern $S_I S_{II} S_{III}$ was seen in 3 cases. The duration of the complex was 0.10 sec in 3 cases, and 0.08 in 6 cases. The electric position of the heart was 10 times horizontal in unipolar limb leads; owing to atypical ventricular tracings it was indeterminate in 2 cases. The height of R aVR was between 4 and 8 mm also in these cases.

The pattern rsR′, characteristic of atrial septal defect and indicating right ventricular hypertrophy, was predominant in the precordial leads. We saw, on the right side of the chest, the pattern rsR′ in 10 cases and the pattern rR′ in 2 instances; the amplitude of R reached 8 mm in 10 cases and was higher than 8 mm in 2 instances.

The left chest leads showed in most cases the Rs or qRs pattern usual with the left ventricle, while the configuration Rs, indicative of pronounced right ventricular hypertrophy occurred only in 2 cases. The height of R V_6 did not exceed 24 mm in any of the cases and did not, thus, reach 26 mm or more, i.e. the amplitude observed in true left ventricular hypertrophy.

Repolarization disturbances are rare in the ostium-primum type of atrial septal defect. It was but in a single case that a marked depression of the S—T segment was observed on the right side of the chest. The axis of the T wave was mostly in mid-position.

The defect of the ostium-primum type means, as a rule, a serious load for the heart, so that the ECG tracings often show an alteration of the P wave, prolongation of the P—Q interval, broadening of the QRS complex, increased voltage of the R aVR, and the pattern rsR′ on the right side of the chest (83 per cent), signs of right ventricular overwork.

The most characteristic feature of the primum type is the left axis deviation. The cause of its preponderance is not clear. It was originally suggested that a mitral insufficiency provoked by the endocardial cushion defect induces hypertrophy of the left ventricle which leads to a preponderance of the left side. However, later investigations [1, 13] proved that left axis deviation occurred also in cases where the mitral valve was intact and the left ventricle was not hypertrophic. It is now universally accepted [13, 40] that the left axis shift is due to a developmental anomaly of the conduction system, an invariable concomitant of the endocardial cushion defect syndrome. According to LUCAS et al. [29], the conduction system of the left ventricle is, owing to the anomaly, elongated and situated downward and forward.

The vector loop, constructed from the synchronous standard leads, is characteristic. Its rotation is counterclockwise, and its major part is above the zero line. The vector loop in the frontal plane is particularly important when, owing to right bundle branch block, the QRS complex has an atypical shape and determination of the electrical axis is complicated. It may happen in such cases that the construction of the vector is not sufficient and that only a loop recorded by the vectorcardiograph affords reliable information. The loop may have the shape of a lying figure-of-eight with irregular course; the direction of the initial part (which invariably rotates counterclockwise) serves as a guide in such cases.

Since, according to the foregoing, in cases of atrial septal defects of the ostium-primum type there is always a shift of the axis to the left in the standard leads, and since, further, the rotation of the loop is invariably counterclockwise in the frontal plane, on the evidence of the ECG and VCG it is usually easy to distinguish between this type of defect and those of the secundum type. The patterns obtained in chest leads and the horizontal loop are, on the other hand, the same in both types: they indicate right ventricular hypertrophy and a local hypertrophy of the outflow tract.

Recent surgical experience [2, 38] has shown that — if the defect of the secundum type extends almost to the atrio-ventricular area — a left axis deviation and a counterclockwise rotation of the vector loop may occur also in this type of atrial septal defect. Although this possibility diminishes the differential diagnostic value of the ECG, it should be borne in mind that ECG-tracings of that type are extremely rare, and that it is better to apply extracorporeal circulation superfluously than to expose the patient to grave hazards by operating under simple hypothermia in cases of the primum type which cannot be repaired in this manner.

Our material included the following four cases in which an atypical ECG made it necessary to apply extracorporeal circulation.

R. K., female, 7 1/2 years of age. ECG: PQ = 0.20 sec. Broad $P_{II} \cdot {}_{III}$. Tall V_{1-6}. Left deviation. QRSα = $-90°$. Position of heart, horizontal. R in aVR R = 4 mm. rsR′ in $V_1 \cdot$ R = 8 mm. RS in V_6. Atypical vector loop with narrow initial part; initial forces definitely counterclockwise. Diagnosis at surgery: extensive defect of the secundum type.

P. M., male, 9 years of age. ECG : PQ = = 0.16 sec. Left axis deviation. QRSα = = $-30°$. Position of heart, horizontal. R in aVR = 6 mm. rsR′ in V_1. R = 6 mm. RS in V_6. Vector loop : counterclockwise rotation in the horizontal plane. Major part of loop situated above the iso-electric line. Diagnosis at surgery : deep defect of the secundum type situated near the atrioventricular valves.

I. N., female, 6 years of age. ECG : PQ= = 0.15 sec. P_{II} tall, peaked. Left axis deviation; QRSα = $-150°$. Position of heart, horizontal. R in aVR = 8 mm. rsR′ in $V_1 \cdot$ R = 10 mm. qRs in $V_6 \cdot$ R = = 16 mm. Vector loop : irregular, suggestive of lying figure-of-eight. Initial forces counterclockwise. Diagnosis at surgery: large defect of the secundum type.

S. I., male, 13 years of age. ECG : PQ = = 0.14 sec. Left axis deviation. QRSα = = $-41°$. Position of heart, horizontal. R in aVR = 2 mm. rs in V_1 and qRs in V_6. R in V_6 = 34 mm. Catheter entered the left atrium. Vector loop counterclockwise, with its major portion above the isoelectric line.

The ECG pattern was not characteristic of atrial septal defect. The left axis deviation and the horizontally positioned heart were not accompanied by signs of right ventricular hypertrophy and incomplete right bundle branch block; the R wave was only 2 mm high in the aVR lead, while the left ventricle was markedly hypertrophic (R in V_6 = 34 mm), a phenomenon unusual in atrial septal defect.

The ECG was atypical, and the operation was therefore performed with extracorporeal circulation. Surgery revealed an atrial septal defect of the ostium-secundum type associated with a ventricular septal defect which had led to the hypertrophy of the left ventricle.

Summary

The two principal types of atrial septal defect have been described. The ostium-secundum type has been observed in 68 children, 29 males (42 per cent) and 39 females (58 per cent). ECG tracings exhibited the following characteristic features. Right axis deviation; vertical position of the heart; right atrial hypertrophy indicated by tall P waves especially in leads II, aVR and V_2. Dilatation of the right ventricle and local hypertrophy of the outflow tract caused

a broadening of the QRS complex and the appearance of the peculiar pattern rsR′ or rRs in right-side chest leads. The pattern qRs with a tall R wave was frequent in left chest leads; the probable explanation of the phenomenon is that, owing to local hypertrophy of the outflow tract, the relation between the wall of the right ventricle and that of the left ventricle remained unchanged, so that the ECG showed the normal pattern in left chest leads. In cases of atypical ventricular complexes it is necessary to examine also the vector loops. The vector loop showed a clockwise rotation in the frontal plane, and its major portion was below the zero line.

The ostium-primum type of defect has been examined in 12 patients. The most characteristic electrocardiographic features were changes pointing to hypertrophy of the right atrium and right ventricle as in the secundum type and a left axis deviation, presumably caused by a developmental anomaly affecting the conduction system. The rotation of the vector loop was invariably counterclockwise, and its major portion was above the zero line.

Correct differential diagnosis is of decisive importance since the surgical method is different in the two types of the defect. While the secundum type can be repaired in hypothermia, extracorporeal circulation cannot be dispensed with in cases of the primum type.

A few cases are described in which the ECG and the vector-cardiogram pointed to the primum type, whereas an extensive atrial septal defect of the ostium secundum type was found at surgery. Despite occasional exceptions, the guiding principle must prevail that in cases suspicious of the ostium primum type of defect (left deviation, counterclockwise rotation of loop), operation has to be performed with extracorporeal circulation.

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