Dextrocardia and Isolated Lævocardia II : Situs Inversus and Isolated Dextrocardia

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Recently, we have reported 20 cases of isolated lævocardia (Campbell and Deuchar, 1965), and here we are describing 33 cases of dextrocardia with malformations of the heart. These are nearly always present when the heart is on the right side without inversion of the abdominal viscera (isolated dextrocardia), as they are with isolated lævocardia: generally they produce a right-to-left shunt and the patient is cyanotic.

Complete situs inversus, on the other hand, is most often found incidentally in a subject whose heart is normal in every other way, but its presence does not exclude the occurrence of other malformations. Among any large group of patients with malformations of the heart, there will be some with situs inversus, and the proportion of 0.8 per cent shown in Table I is so much above that found in the general population that situs inversus must be associated with some extra liability to other malformations of the heart. The proportion so affected, one in each four or five (Campbell, 1963), is much greater than has generally been supposed.

Among our first 670 patients with cyanotic congenital heart disease (1947-53), the proportion with situs inversus is 1 per cent (Table I) and the proportion with isolated dextrocardia is larger (2.8%). The corresponding proportion among patients with acyanotic congenital heart disease (CHD) is much less, 0.4 per cent. Berri (1958) found a similar proportion with dextrocardias (2.2%) among 2695 patients with congenital heart disease in the service of the Hospital de Niños de Buenos Aires.

Since then (1953) we have seen 5 other examples, making 33 in all, but do not know the number of patients with CHD from which they were selected. The sex and age distribution of these 33 with dextrocardia are shown at the bottom of Table I. There were about equal numbers of each sex. Nearly 80 per cent were under 10 years when first seen and

only 3 (9%) were over 20 years of age. We have seen relatively few infants, aged 3 years and under, with these or other malformations of the heart, but think the proportions of children of other ages and of adults are representative of the total number living. The mortality, therefore, must be heavy.

In this paper we are reporting our findings in 29 of the 33 cases of dextrocardia shown in Table I, since the other 4 have not had any special investigations: all of them had other malformations of the heart, and all but one were cyanotic. We are classifying them on a simple factual basis according to the position of the abdominal viscera and the venæ cavæ and venous atrium: and later we shall discuss whether those with a right-sided venous atrium are due to dextro-rotation rather than inversion.

Cases with malformations of the heart and complete situs inversus are accepted as mirror-images of those with the same malformations of a heart that is normally placed. In fact, all forms of dextrocardia are exact mirror-images of some form of lævocardia: this is often implicit in the authors' discussions but has been emphasized more clearly by Shaher and Johnson (1963). In the classification that follows, Groups D I, D II etc. are mirror-images of Groups L I, L II etc.

When the heart is on the right with the apex pointing to the right, the abdominal viscera may be inverted or they may be normally situated. When the abdominal viscera are inverted, the venæ cavæ and the atria also may be inverted, Group D I, situs inversus totalis (Cases 21-30); or, more rarely, they may appear to be normally situated with the venous atrium on the right, Group D II, incomplete situs inversus (Case 31 only).

When the heart is on the right without inversion of the abdominal viscera (isolated dextrocardia), the venæ cavæ and atria may be normally placed, i.e. with the venous atrium on the right in agreement with the abdominal viscera: this is the commonest form of isolated dextrocardia (Group D III; Cases

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TABLE I
INCIDENCE OF DEXTROCARDIA AND AGE DISTRIBUTION

	Total No. with CHD	No. with inversion		Situs inversus	Isolated dextrocardia	Isolated lævocardia
		Total	Percentage			
Cyanotic	670	38	5.7	7 (1.0%)	19 (2.8%)	12 (1.8%)
Acyanotic	460	4	0.9	2	0	2
Total	1130	42	3.7	9 (0.8%)	19 (1.7%)	14 (1.2%)

	Total	Sex		Age distribution (years)				
		M	F	0-4	5-9	10-14	15-19	20 and over
Situs inversus	11 (3)*	4	7	4	3	2	0	2
Isolated dextrocardia	22 (1)*	12	10	10	9	0	2	1
Total	33	16	17	14	12	2	2	3

* The numbers in brackets are the number of acyanotic cases, already included in the total.

32-47). Alternatively the venæ cavæ and atria may appear to be inverted in the same way as the heart as a whole: this is a less common form of isolated dextrocardia (Group D IV; Cases 48-49). We shall discuss whether the cases in Groups D II and D IV are really examples of the asplenia syndrome and whether this prevents a clear decision about the situs of the abdominal viscera. The cases we are describing here have been numbered from Case 21 onwards to emphasize the relationship with Cases 1-20 of our series with isolated lævocardia.

Assuming that the ventricles themselves may be inverted without producing a heart on the right side (as they are in bulbo-ventricular inversion in a heart that is normally placed), each of these groups may be subdivided into those where the ventricles are inverted and those where they are not. Where the ventricles behave in the same way as the atria, this is indicated by the suffix *a* after D III etc., and where they behave differently, i.e. atria normally placed and ventricles inverted or vice versa, by the suffix *b*. In practice, this distinction is often difficult on clinical grounds and may be impossible without a necropsy. We shall consider this as far as we can, but are aiming at a classification that can be used in clinical work, so have not always decided this point. Axial inversion of the ventricles alone probably occurs at a later embryonic stage than mirror-image inversion of the heart as a whole, and this will be discussed later.

PATIENTS WITH SITUS INVERSUS: GROUPS D I AND II

We have seen 11 patients with situs inversus and other malformations of the heart, 8 being cyanotic and 3 acyanotic. Some details about them are shown in Table II, the situs inversus being regarded as complete in the first 10 but as incomplete in 1

(Case 31), who was probably an example of the asplenia syndrome.

Situs Inversus Totalis: Group D Ia. Ten were classified in this group. So far as we know all of them had complete situs inversus of the abdominal viscera except that in Case 30 it was marred by a duodenum inversus. They all had T inversion in lead I, but inversion of PI was less constant than with situs inversus and a heart otherwise normal. PI was always inverted in 5 and usually so in a sixth (Case 24). In 2 others it was often inverted: in one of these it was often upright, and then P was generally inverted in leads II and III (Case 21); and in the other there was nodal rhythm at first visits and later this or complete A-V dissociation (Case 25). In the ninth, PI was sometimes inverted with a P-R interval of 0.20 sec. and sometimes upright with one of 0.15 sec. (Case 30, Fig. 1A). In the tenth, PI was often flat but sometimes small and biphasic (Case 27). Some of the unusual examples are shown in Fig. 1.

The superior vena cava (SVC) was on the left side in all 10 patients. This was the only SVC in 7 (certainly in 6 and probably in Case 28 who did not have angiocardiology). In the 3 others there was a SVC on the left and a persistent right SVC as well, but it drained through the coronary sinus into the left-sided (venous) atrium (Cases 23, 26, and 27). The venous atrium was, therefore, on the left side, so was presumably a right atrium inverted like the SVC and the abdominal viscera in all 10 patients.

In Case 26, the only one with a necropsy, the ventricles were inverted as well as the atria. We think that they were inverted in all the others, though we cannot be sure of this.

The aortic arch was right-sided in 9 of the 10 patients. In the tenth (Case 27), who had Fallot's tetralogy, it was left-sided, but this is no more sur-

TABLE II
SOME DETAILS OF 11 PATIENTS CLASSIFIED AS SITUS INVERSUS

Case No.	P in lead I	Drainage		Aortic arch	ASD	VSD	Aorta from	Pulmonary trunk from
		SVC	Pulmonary veins					
			Acyanotic cases					
21	Inverted, upright	L to LA*	RA*	R	++	No	RV*	LV*
22	Inverted	L to LA	RA	R	++	No	RV	LV
23	Inverted	B† to LA	RA	R	No	++	RV	LV
			Cyanotic cases					
24	Generally inverted	L to LA	RA	R	+++	No	LV	?
25†	Inverted and upright	L to LA	RA	R	+++	++	RV LV	RV LV
26	Inverted	B to LA	RA	R	++	++	LV	LV
27	Small biphasic	B to LA	RA	L	No	++	RV LV	LV
28	Inverted	L to LA	?RA	R	?No	?+	—	—
29	Inverted	L to LA	RA	R	No	+++	(RV) LV	LV
30	Upright, inverted	L to LA	?	R	?No	?No	?LV	?RV
			Without inversion of the atria					
31	Generally upright	R to RA	LA	R	No	+++	RV	?

In Cases 21–30 the atria were inverted and we think the ventricles were, but in Case 31 the atria were not inverted and we are uncertain about the ventricles.
* RV and LV stand for right-sided and left-sided ventricle; RA and LA stand for right-sided and left-sided atrium respectively.
† Case 25 has been reported fully with a cousin who had isolated lœvocardia (Case 18) by Campbell and McCarthy (1957).
‡ B = both R and L superior venæ cavæ.

Fig. 1.—Upright and inverted P waves in lead I in some less usual electrocardiograms of situs inversus. All lead I. (A) On the left, upright P waves when lying flat. On the right, inverted P waves when lying on the left side. Case 30. (B) Inverted P waves with complete heart block. A, 90; V, 59 a minute. Case 28. (C) Changes between inverted PI (rate about 70–75 a minute) and upright PI (rate about 100–120 a minute). Case 31.

Fig. 2.—Angiocardigrams of Case 31 with apparent situs inversus, complete except for the atria (? asplenia syndrome) and pulmonary stenosis. At 1 sec., filling of right SVC and right-sided atrium. At 2 sec., filling of right-sided ventricle and the enormous coiled aorta. At 3 sec., less filling of the heart, but some of the aorta, especially the descending aorta; and still very slight filling of the lungs.

prising than the frequent occurrence of a right-sided aortic arch in ordinary patients with Fallot's tetralogy.

Incomplete Situs Inversus: Group D II. This contained only one patient, in whom the SVC and atria were not inverted but the stomach was: the liver was thought to be bilateral, and probably she was an example of the asplenia syndrome.

Case 31. A girl, aged 4, was severely disabled and cyanosed. The stomach was inverted, the very large heart was on the right, and the aortic arch was right-sided, so at first she was thought to have complete situs inversus, though PI was generally upright, and when inverted it was at a slower rate (Fig. 1C).

On angiocardigraphy, however, the opaque medium passed down a right SVC to a right-sided atrium that was in the normal position of a right atrium in relation to the chest, though nearer the centre of the heart shadow than normal, because of the dextroposition of the heart (Fig. 2). This atrium was so far over to the right, that the other must have been to its left or behind it, though it was not clearly visualized. At 2 sec. the opaque medium filled the right-sided ventricle, well out to the right border, and from it passed to an enormous dilated aorta (Fig. 2(2)) that formed a semicircle passing upwards to the left of the heart shadow before curving across and descending on the right. At 3 sec. the density of the heart shadow was fading and the pulmonary trunk was seen end-on inside the aortic loop just to the left of the mid-line (Fig. 2(3)): it was not certain if it had filled from the left-sided ventricle through a large VSD or if there was a common ventricle.

The catheter from the left arm failed to show a left SVC and passed down the right SVC; the O_2 saturation in the right atrium and SVC (54 to 58%) was not much below that in the femoral artery (63%); and no ventricle could be entered. She was thought to have a large VSD or more likely a common ventricle and severe pulmonary infundibular stenosis. The aorta lay to the left of the

pulmonary trunk in which the pressure at operation was found to be very low; it was uncertain if there was transposition. There was an enormous azygos vein joining the right SVC, so probably this drained the lower part of the body and there was no normal IVC.

She improved greatly after subclavian-pulmonary anastomosis when 9 years old. Two years later she developed bacterial endocarditis and, though this infection was cured, she died with congestive heart failure a year later. Unfortunately there was no necropsy.

OTHER MALFORMATIONS OF THE HEART, AND PROGNOSIS: GROUPS D I AND II

Three of the 11 patients were *acyanotic*. A man had atrial septal defect (ASD) and at first the veins from the left lung were thought to drain into the left-sided (morphological right) atrium but more likely a pulmonary vein had been entered through an ASD (Case 21). A woman had classical atrial septal defect (Case 22). The third, a boy aged 3, had a ventricular septal defect of moderate size and, after full investigations when he was 11, corrected transposition of the great vessels also was found (Case 23).

Of the 8 *cyanotic* patients, 3 had Fallot's tetralogy (Cases 27, 28, and probably 25). Four others had pulmonary stenosis with additional complications, so that all except Case 30 had pulmonary stenosis.

There was an ASD in 2 of the 3 *acyanotic*, and in only 3 of the 8 *cyanotic* patients. There was a VSD in 1 of the 3 *acyanotic*, but in far more of the *cyanotic* patients—in 6 of the 8, and we are not certain of its absence in the other 2 (Cases 24 and 30). The septal defects were thought to have been so complete that there was a common atrium in Cases 24 and 25 and a common ventricle in Cases 29 and 31, but in none of these was it proved by a necropsy.

The aorta arose from the right-sided (morphological left) ventricle and the pulmonary trunk from the left-sided (morphological right) ventricle in all the acyanotic patients, as they do in uncomplicated situs inversus. This was probably so in Case 31 with incomplete situs inversus, where the cyanosis was caused by the absence of inversion of the atria and venæ cavæ. It was not the case in any of the 7 cyanotic patients with complete situs inversus. Certainly in 3 (Cases 25, 27, and 29), and probably in 1 other (Case 28), the aorta overrode the VSD and both ventricles: in 3 of these the pulmonary trunk arose from the left-sided ventricle but in the fourth (Case 25), it too overrode the VSD. In the other 3 (Cases 24, 26, and 30) the aorta arose from the left-sided (morphological right) ventricle, and the pulmonary trunk varied in its ventricular origin (see Table II). In Cases 26, 29, and 30, and probably 24, there was transposition of the great vessels, rather than simple inversion.

In 3 of the 8 cyanotic patients and probably in a fourth, there was no IVC and the drainage from the lower part of the body was through an azygos vein that entered the left SVC (Cases 25, 26, 29, and probably 31).

Some of these malformations show that, even with complete situs inversus, there is often difficulty in the spiral septation of the truncus arteriosus meeting the ventricular septum accurately (though not perhaps as often as with isolated dextrocardia and isolated lævocardia), and also in the development of the inferior vena cava.

In addition to these malformations of the heart, Cases 21 and 29 were known to have moderately severe bronchiectasis, Case 23 had had a successful operation for hypospadias, and Case 29 had Turner's syndrome.

Prognosis. The progress of these 11 patients was what might be expected from their associated malformations, unaffected by the situs inversus. Of the 3 who were acyanotic, the man with ASD had few symptoms when he was 18 and has got on well for another 15 years (Case 21). The woman with ASD got on well till she was 45 and lived another 5 years with pulmonary hypertension, partial reversal of her shunt, pulmonary regurgitation, and atrial fibrillation (Case 22). The boy with VSD has not changed much in 12 years, though he has become a little cyanotic on exertion (Case 23).

The malformations in the cyanotic patients were more serious and complex, so the outlook was worse. Three of the 8 died in early childhood: one after operation (Case 26), one after subacute bacterial endocarditis (Case 31), and the third 5 years after we had seen her and we cannot find the cause of death

(Case 30). The first two had been severely, and the third moderately, disabled for several years.

Three others have got on moderately well for between 7 and 9 years and operation has not been advised, though their disability is enough to make this desirable if they had more straightforward malformations (Cases 24, 25, and 29). The two last have, however, got on well for 16 years (Cases 27 and 28). Short accounts of these two and the only patient with a necropsy follow.

Case 27. A girl, aged 11, had Fallot's tetralogy with no other complications than her situs inversus and a left-sided aortic arch. She got on well for 16 years after a subclavian-pulmonary anastomosis, but in the 17th year was admitted with atrial fibrillation and congestive failure: normal rhythm was restored but her outlook is now more uncertain.

Case 28. A girl, aged 14, with complete heart block (Fig. 1B) and probable Fallot's tetralogy had few symptoms. Sixteen years later, she had married and adopted a child, and felt so well that she was unwilling to come to hospital for any investigations. (Denolin (1950) also has reported a case with situs inversus and complete heart block, associated in his case with a VSD only.)

Case 26. A girl, aged 5 at her death after operation, had been seriously disabled. *Necropsy* showed a large ASD and a moderate-sized VSD. The aorta and pulmonary trunk both arose from a left-sided (morphological right) ventricle, and there was severe pulmonary stenosis. The ductus arteriosus was right-sided and patent. A large azygos vein drained the lower part of the body as there was no normal IVC; it joined the left-sided (and only) SVC.

PATIENTS WITH ISOLATED DEXTROCARDIA

Our findings in this section are based on the 18 patients with isolated dextrocardia and other malformations of the heart who have had special investigations. Although the heart was in the same position as in those with situs inversus, the SVC and venous atrium were on the right as normally in 16 of the 18 cases, i.e. the opposite to what was found in those with complete situs inversus. With only two exceptions in this group, therefore, and one in the situs inversus group, all the cases followed the general rule that the venæ cavæ and venous atrium were inverted when the abdominal viscera were inverted, and not inverted when the abdominal viscera were normally placed (see discussion).

WITH VENÆ CAVÆ AND VENOUS ATRIUM ON THE RIGHT (GROUP D III: 16 CASES, No. 32-47)

Our 16 examples of this group, all but one cyanotic, are fairly homogeneous except for the associated malformations and the degree of rotation of the ventricles. This group is often referred to as

TABLE III

MAIN FEATURES IN 9 CASES OF ISOLATED DEXTROCARDIA WITH NECROPSIES

Group and Case No.	ASD or common atrium	Inversion of ventricle and VSD	Venous atrial blood to	Aorta from	Pulmonary trunk from	Other malformations
D IIIa { 38 41 44	No Common Common	Not inverted, VSD Not inverted, VSD Not inverted, VSD	RV* on right RV on right RV on right	RV* (right) RV and LV LV* (left)	LV and RV Atretic (LV) LV	Pulmonary stenosis, PDA Pulmonary atresia, PDA Common atrium and A-V valve
D IIIb { 36† 42 43‡	Common Large ASD PFO§	Inverted, VSD Inverted, VSD Inverted, VSD	LV* on right LV (right) to RV RV on left	RV (left) RV (left) RV	LV RV LV	Common atrium and A-V valve Slight infundibular stenosis Severe infundibular stenosis PDA
D III { 32 34 37‡	Common ASD ASD ASD	Common ventricle Common ventricle Common ventricle		Truncus arteriosus Aorta in front of PT Aorta to right of PT		Cor biloculare PVS, tricuspid atresia PVS

* RV and LV indicate the morphological ventricle.

† The rare type of mixed dextrocardia with cross connections (Lev and Rowlatt, 1961).

‡ These two have been fully reported: Case 36 as Case 53 of Brinton and Campbell (1953), Case 37 as Case 4 of Campbell, Reynolds, and Troughton (1953).

§ PFO = patent foramen ovale.

dextroversion, but whether this denotes a different developmental mechanism to mirror-image development on the other side or is merely a convenient descriptive term will be discussed later.

By definition, the heart was on the right side with the apex pointing towards the right in every case, and the abdominal viscera were normally placed so far as we know after clinical and x-ray examination, and at necropsy in the 9 where this was available, though not completely so in Case 42. Here the lungs had three lobes on the left and two on the right side and the liver had lobes of almost equal size on each side: the spleen had two lobes and there were four splenicula, the largest being 5 cm. long compared with 15 cm. for the spleen itself.

In all, there was a right-sided SVC draining into the right-sided venous atrium or the right side of a common atrium. In 4 cases there was a persistent left SVC as well as that on the right: it drained into the right-sided atrium through the coronary sinus in Cases 32, 33, and 46, but in Case 44 into the left side of the common atrium, and no coronary sinus could be found. In 11 of the 16 cases, the IVC also drained into the right-sided atrium and in 3 others we have no reason to think that it did not do so. In Cases 42 and 44 (proved by necropsy) the venous drainage from the lower part of the body was through an azygos system that drained into the right SVC and there was no normal IVC.

In every case where the atria were differentiated, the venous atrium was on the right side, almost as usual relative to the chest but not to the heart. In 5, however, there was substantially a common atrium (see later). In all, the available evidence was that the pulmonary veins drained into the left-sided atrium, or the left side of a common atrium, except that in Case 42 the veins from the right lung entered

the right atrium, those from the left entering the left atrium as usual.

The aortic arch was left-sided in 14 but was right-sided in 2 (Cases 36 and 42, both with necropsies).

Lead I was characteristic of isolated dextrocardia in that it consistently showed inversion of TI and usually Q waves in lead I (Fig. 3). Corresponding with the arrangement of the atria (venous atrium right-sided) PI was generally normal and upright: it was always upright in 12 though rather small in 3 of these; it was biphasic in 1 (Case 36, with necropsy); and it was more often upright but sometimes inverted in 2 (Cases 33 and 39). In the sixteenth (Case 42) it was usually upright and large, but sometimes inverted and then large or small and biphasic.

The determination of the *position of the venous and arterial ventricles* is generally simple in these cases. But the identification of *their morphological status* is likely to be difficult, and many of the hearts in this series are not now available for re-examination. In 3 of the 9 with necropsies, there was a common ventricle (Cases 32, 34, and 37). In 5 of the remaining 6 the venous ventricle was on the right, as might be expected if the venous atrium were on this side. In Case 43, however, the right-sided atrium connected with a left-sided ventricle and vice versa, the tricuspid valve being anterior to the mitral valve, and the two atrio-ventricular passages being almost at right angles to each other. This was, therefore, an example of the rare type of mixed dextrocardia (Lev and Rowlatt, 1961) where there is a cross connexion of the atria and ventricles.

We thought the right-sided ventricle was a morphological right ventricle in Case 41, and less certainly in Cases 38 and 44; but a morphological left ventricle in Cases 36, 42, and 43 (see Table III). In

Fig. 3.—Electrocardiographic changes in lead I characteristic of isolated dextrocardia—an upright PI with TI inversion and often QI. (A) Case 42, (B) Case 40, and (C) Case 43, each with a relatively large QI. (D) Case 32, and (E) Case 46, each with a much smaller QI.

the other 3 with necropsies there was a common ventricle.

In 6 of the 7 without necropsies, the venous ventricle was right-sided, and in Case 46 venous and arterial blood mixed in the left-sided ventricle as there was tricuspid atresia. We thought on clinical grounds that the ventricles were morphologically inverted in Cases 35 and 45, but in the others the evidence was incomplete and there could have been

rotation of the heart about the long axis of the body without any inversion.

There was some variation in the degree of rotation of the heart round its own axis. Thus in Cases 41 and 45 the left-sided ventricle was completely to the left of and in the same frontal plane as the right-sided ventricle (Fig. 4). On the other hand, in Cases 35 and 43 the left-sided ventricle was very anterior to the right-sided ventricle. This did not

Fig. 4.—In each of the three drawings, the larger probe, A, passes from the left ventricle to the aorta, and the smaller probe, B, passes from one ventricle to the other through the VSD. Case 41. (a) The heart rotated further to the right (anti-clockwise from below) and opened to show the left ventricle in front. (b) The heart in its natural position unopened; the right ventricle was on the right and the left ventricle on the left. (c) The heart rotated and swung over to the left with the right ventricle in front.

Fig. 5.—Angiocardiograms from Case 34. (A) At 1 sec., opaque medium in right SVC and right atrium passing through ASD to left atrium, because of tricuspid atresia. (B) At 2 sec., opaque medium filling both atria, the left side of the common ventricle (necropsy control), and less completely its right side. (C) The large anterior aorta filled from the left side of the common ventricle, with the pulmonary trunk lying directly behind it. There was, however, little filling of the lungs because of severe pulmonary stenosis, which was later relieved by pulmonary valvotomy.

depend on the morphology of the ventricle, since the anterior one was morphologically a left ventricle in Case 35 and a right ventricle in Case 43.

The origins of the *aorta* and *pulmonary trunk* were very varied in the 9 with necropsies (Table III), though there was transposition of the great trunks in 7 of the 9, in the sense that the aorta was anterior to the pulmonary trunk. Only in one (Case 38) was the aorta posterior as normally. In the ninth (Case 32) there was a truncus arteriosus, arising from a common ventricle of a bilocular heart.

In 2, the aorta arose from the left-sided ventricle (arterial in Case 36 but venous in Case 43), and the pulmonary trunk, which was normal in Case 36 but small and stenosed in Case 43, from the right-sided ventricle. In Cases 42 and 44, the aorta again rose from the left-sided (arterial) ventricle, but the pulmonary trunk, with slight pulmonary or infundibular stenosis in both, arose from the same ventricle (see Fig. 6). In Case 41 the aorta overrode both ventricles while the atretic pulmonary trunk was attached to the left-sided ventricle.

In Case 38, the only one where the aorta was posterior to the pulmonary trunk and there was no transposition, the aorta arose from the extreme right side of the right-sided (venous) ventricle and the pulmonary trunk overrode both ventricles. Finally, in the three cases with a common ventricle, the aorta arose just in front of the pulmonary trunk in Case 34 (Fig. 5), a little to the right of it in Case 37, and there was a truncus arteriosus in Case 32.

In those without necropsies, there was a similar variety. There was complete corrected transposition of the great vessels in Cases 35 and 45; and transposition in Cases 40 and 47, but the aorta overrode both ventricles. In Case 46 with tricuspid atresia, we are uncertain if the pulmonary trunk arose from the left, or from the right ventricle through a VSD. In Case 33, there seemed to be a normal arrangement of the great trunks, and in Case 39 they filled simultaneously but we are uncertain of their origins.

One patient who was under observation for 16 years and finally came to necropsy will be described.

Case 42. This young man led an active life, married, and had three normal children, in spite of moderately severe cyanosis with a hæmoglobin of 140 per cent and many malformations of his heart. He was seen from the age of 17 till his death at 33 years. In his twenties he was a keen cyclist and rode up to 20 miles, making great efforts to keep up with his fit twin brother. When 24, paroxysms of atrial fibrillation started and often led to his admission with signs of heart failure. When 29, he was still working and could walk a few miles but after this he lost ground and could not work the last 3 years of his life.

At necropsy, his heart weighed 649 g. The right-sided SVC and the hepatic vein entered the right atrium; and the drainage from the lower part of the body was through an azygos vein that entered the right SVC, without a normal IVC. The pulmonary veins from the left lung entered the left atrium, but those from the right lung drained into the right atrium.

Fig. 6.—The heart of Case 42 who was not greatly disabled for 30 years, in spite of multiple malformations. The small inset shows how the front of the heart was cut at the lines indicated by the arrows. The narrow central segment was turned upwards across the aorta, the lower segment was turned downwards, and the other two to the right and the left respectively. The main picture shows the common A-V valve and the interior of the two ventricles, with the aorta (on the left of the heart and slightly anterior) and the pulmonary trunk (on the right and just posterior to the aorta), arising nearly side by side from the large left-sided (but probably morphological right) ventricle. The probe passes from the left-sided ventricle through the VSD, this connecting with the large ostium primum, to the lower part of the right-sided ventricle, which was much smaller and had no arterial outlet. For other malformations see text.

In addition to the absence of an IVC and partial anomalous pulmonary venous drainage, there were a large ostium secundum (3 by 3 cm.), an ostium primum, and a single A-V valve with large anterior and posterior cusps (Fig. 6) and two much smaller lateral cusps, and a large ventricular septal defect (4 by 5 cm., the upper part of the ostium primum being 1 by 5 cm.). The right-sided ventricle had no arterial outlet. Both the aorta and pulmonary trunk arose from the large, posterior left-sided ventricle, which was probably a morphological right ventricle. Thus, the ventricles were inverted though the atria were not. The aorta arched to the right, and there was partial transposition of the great vessels, as the aorta was anterior and rather to the left of the pulmonary trunk which arose from the same chamber above a slight infundibular stenosis.

The coronary arteries arose from the normal coronary ostia. The left ran down the groove over the inter-ventricular septum, but its circumflex branch ran to the right; and the right artery ran to the left, i.e. inverted.

The lungs were inverted and the liver was centrally placed. Otherwise the abdominal viscera were normally placed, though the spleen (15 cm.) had two lobes and four large spleniculi, up to 6 cm. in length. He was, therefore, an example of the asplenia syndrome.

WITH VENA CAVA AND VENOUS ATRIUM ON THE LEFT (GROUP D IV: 2 CASES, NO. 48 AND 49)

There are only two examples of isolated dextrocardia with a left-sided SVC. This drained into a left-sided atrium or perhaps in Case 49 into the left side of a common atrium. Corresponding with this, PI was inverted in Case 48, and most often inverted in Case 49, but often small and upright and then at a rather faster rate, and sometimes just after QRS with nodal rhythm.

In both, the drainage from the lower part of the body was through an azygos vein that joined the left SVC and there was no normal IVC.

In both, the venous ventricle was left-sided, and in Case 49 it was almost certainly a morphological left ventricle, though placed anteriorly and rather horizontally. In Case 49 and, less certainly, in Case 48 there was no VSD. In both, the aorta arose from this ventricle and at an unusually sharp right-angle in Case 49 (Fig. 7). The aortic arch, however, was left-sided in both, as it was in most cases of Group D III. We have no direct evidence that these two patients had the asplenia syndrome.

Case 48 is reported more fully. A girl, aged 3, had always been slightly cyanosed (grade 2; hæmoglobin, 90–108%). She was not much disabled in spite of an enormous heart (c.t.r. 65%). A loud continuous murmur could be heard on the right side. As a small child she could walk a mile and slowly improved till she could walk six miles and play some tennis. She is now 19 and keeps very well.

At angiocardiology when she was 6, the opaque

medium entered a venous atrium on the left (Fig. 8A), and the pulmonary veins from the left lower lobe entered this atrium. From it, the opaque medium passed to a left-sided venous ventricle and to the aorta (Fig. 8B); and probably through an atrial septal defect to the right-sided ventricle, as the pulmonary trunk filled soon after the aorta. At 3 seconds, the aortic shadow was fading but the lungs were still filling well; at 4 and 5 seconds the right-sided atrium, to the right of and above the left-sided venous atrium, was filling enough to produce a second opacification of the aortic shadow.

At catheterization no SVC could be entered from the

Fig. 7.—A-P view of angiogram of Case 49. The catheter has passed down a left SVC to a left-sided atrium and a left-sided (morphological left) ventricle, where the opaque medium was injected. At 2 sec. it has passed to the large aorta which leaves the left ventricle at a sharp angle and arches to the left. The lungs did not fill till later.

right arm. From the right saphenous vein, the catheter passed upwards to above the hilum of the left lung where it turned down, through an azygos vein, into the left SVC and the left-sided atrium: no IVC was intubated, but the lower left pulmonary veins, the coronary sinus, and the hepatic veins from both lobes of the liver were intubated.

From this left-sided atrium, the catheter entered a left-sided ventricle reaching near the apex. It passed on to enter the pulmonary trunk and its left branch, probably through an ASD as the pulmonary trunk filled with opaque medium later than the aorta. The systolic pressures in this ventricle (87/3), in the pulmonary trunk (88/54), and in the brachial artery (90/65) were substantially the same. This was also the case with the oxygen

Fig. 8.—A-P angiocardiograms of Case 48. At 1 sec. the opaque medium has passed down a left SVC to a left-sided atrium and a left-sided ventricle. Some of the pulmonary veins were thought to drain into the left-sided atrium where indicated by arrows. At 1.5 sec. it has entered the aorta; this passes vertically upwards and arches to the left, but it is quite unlike that of Case 49 shown in Fig. 7. The large pulmonary trunk filled later than the aorta and indented the left SVC.

percentage saturations (SVC, 76%; atrium, 83%; ventricle, 87%; pulmonary trunk, 85%; and systemic artery, 83%).

The pulmonary blood flow was about twice normal. There was almost complete mixing of venous and arterial blood at atrial level, partly from anomalous pulmonary venous drainage but also probably through the ASD.

ASSOCIATED MALFORMATIONS AND PROGNOSIS IN ISOLATED DEXTROCARDIA (BOTH GROUPS, 18 CASES)

Associated Malformations. In 15 of the 18 cases, there was a defect of the atrial septum, usually a large one, and in 5 of them there was a common atrium, proved by necropsy in 4 (Cases 32, 36, 41, and 44) and suggested by investigations in the fifth (Case 49). There was a patent foramen ovale only in one other (Case 43, with necropsy control). There was no communication between the two atria in one case with necropsy control (Case 38) and, we think, in the only patient who was acyanotic (Case 33).

Sometimes when there is a large atrial septal defect it is difficult to determine by angiocardiography if there is a ventricular septal defect also, as both ventricles may fill simultaneously. In 13 of the 18 there was good evidence of a defect of the ventricular septum and in 3 of these there was a common ventricle (Cases 32, 34, and 37, all with necropsies). We thought there was no VSD in Case 49 and were uncertain in 4 others (Cases 33, 39, 40, and 48). No

patient was *proved* to be without either an atrial or a ventricular septal defect: 12 of the 18 had both atrial and ventricular septal defects.

Pulmonary stenosis was the most common malformation, apart from the septal defects, being present in 9 of the 18 cases, with associated tricuspid atresia in one of these (Case 34, see Fig. 5); and a tenth had pulmonary atresia (Case 41). There was tricuspid atresia alone in one (Case 47) and truncus arteriosus in one (Case 32). The aorta and pulmonary trunk both arose from the left-sided ventricle and there was slight pulmonary stenosis in one (Case 44, with necropsy), and in another there was complete transposition of the aorta and pulmonary trunk with slight infundibular stenosis (Case 43, with necropsy). If these two were included as examples of pulmonary stenosis, it would increase its incidence to 11 of the 18 cases. In one only was transposition of the great vessels the sole additional lesion (Case 36, with necropsy), though as already stated it was present in several of those with pulmonary stenosis and in others.

The three remaining, Cases 40, 42, and 48, were unusual in having an increased blood flow to the lungs and are discussed at the end of the section on prognosis.

Prognosis. Of the 18 patients, most were severely disabled and 10 have died. Five died from their heart condition directly, 3 in their first year (Cases

36, 41 and 44), one at the age of 5 (Case 39), and one at the age of 33 (Case 42); and 3 died after operations, 2 at the ages of 5 and 7 after operations without which they seemed unlikely to live long (Cases 32 and 43), and the third at the age of 20, operation having been advised because he was so dissatisfied with the invalid life that he had to lead (Case 37). Of the remaining 2, one died from a cerebral abscess at the age of 4 (Case 38); and the other after a bronchogram for bronchiectasis at the age of 9, two years after a pulmonary valvotomy had produced great improvement (Case 34).

The other 8 were alive when they were last heard of, and most of them have been followed for several years. Two are fairly well after operations, one aged 16 after a recent pulmonary valvotomy (Case 35), and the other six years after an anastomotic operation at the age of 19 for tricuspid atresia as he had been losing ground during the previous seven years (Case 46). Three are fairly satisfactory without operations—one having kept much the same from the age of 3 to 14 years (Case 49), one aged 5 seen only for the last 4 years and less cyanosed than most (Case 45), and the third with little change from the age of 5 to 20 years (Case 47). The remaining three are able to do more. One, the only acyanotic patient, has got on fairly well from the age of 7 to 14 years and is thought to have moderate pulmonary stenosis (Case 33). The other two, and a third who has died since this was first written (Case 42), are unusual in that the systolic pressures on the right and left sides are almost balanced, and the O₂ percentage saturation is much the same in the "venous" and "arterial" chambers; but as there is no obstruction to the blood flow to the lungs, which is considerably increased, they have got on well in spite of their moderately severe cyanosis, one from the age of 9 to 25 years with a successful pregnancy (Case 40), one from the age of 3 to 19 years (Case 48), and the third from the age of 17 till his death at the age of 33 (Case 42). Cases 40 and 48 were included in our series of patients with continuous murmurs (Campbell and Deuchar, 1961).

ASSOCIATED MALFORMATIONS AND PROGNOSIS IN DEXTROCARDIA AND ISOLATED LÆVOCARDIA

Associated Malformations. The other malformations of the heart found with isolated dextrocardia seem very similar to those with isolated lævocardia, as might be expected. Atrial and ventricular septal defects each occurred in three-quarters or more of both groups; and were large enough to produce a common atrium or a common ventricle, each in about one-quarter of both groups.

Pulmonary stenosis or atresia was the other most common malformation, being present again in three-quarters of each group, and transposition of the great trunks in about the same proportion. Other malformations, e.g. anomalous pulmonary venous drainage, tricuspid atresia, a common A-V valve, and truncus arteriosus, occurred much less often. There is no close association with aortic stenosis, coarctation of the aorta, or persistent ductus arteriosus.

In the cyanotic patients with complete situs inversus, combinations of these malformations were less frequent, though pulmonary stenosis, a VSD, a common ventricle, or a common atrium occurred in nearly as many. Transposition of the great trunks was common, but less so. In the smaller number of acyanotic patients there was generally one simple malformation only.

Rather to our surprise, the absent IVC syndrome was just as common in those with complete situs inversus. It was found in one-fifth (10 out of 49) of the patients of all these groups together.

Prognosis. This seemed to be the same for isolated dextrocardia and isolated lævocardia, and in each group about one-half of our patients have died since coming under observation (19 of 38 in all). Most of the deaths were before the age of 5 and only three died after reaching adult life, two at 20 and one at 33 years. On the other hand, 19 are still alive and many of them have got on reasonably well for up to 16 years, though a few are losing ground. The two acyanotic patients with isolated lævocardia (included in the above figures) have done very well.

Those with complete situs inversus have done rather better. The 3 who were acyanotic all got on well, though one with ASD died when she was 50 years old. Of the 8 who were cyanotic, 3 have died in their first 10 years but only a few of the others are losing ground.

In summary for all the groups together, the small proportions who are acyanotic, or cyanotic with an increased blood flow to the lungs, have done very well for up to the 16 years of our follow-up. Of the others, and they are the great majority, more than half have died in their first decade, mostly in the first five years. The true mortality is greater than this because our series contained relatively few infants. Those who survive the first decade generally continue much the same, most of them moderately disabled but some of them more severely. Simple surgical treatment, anastomotic operations or pulmonary valvotomy where indicated, carries a heavy mortality but has helped greatly a few of our patients.

CLASSIFICATION OF DEXTROCARDIA

Several forms of dextrocardia are recognized. The classification of Brown (1950) may be taken as representative, though his Group (4) where the heart is displaced to the right by non-cardiac malformations, e.g. of the diaphragm, is not considered here.

(1) Dextrocardia with situs inversus (mirror-image dextrocardia); our group D I. This type is generally accepted. Most often the heart is normal except for its position, but we think that the number with other malformations has generally been underestimated (e.g. Grant, 1958).

(2) Isolated dextrocardia (without inversion of the abdominal viscera) with inversion of some or all of the heart chambers; our group D IV. This is a less common and more controversial type, which will be discussed later.

(3) Isolated dextrocardia *without inversion* of the heart chambers; our group D III. Brown thought this the most common form. It is often referred to as dextroversion from the "dextroversio cordis" of Paltauf (1901). Dextroversion is a good description of what seems to have happened and even better if the suggestion of Nagel (1909), re-emphasized by Grant (1958), that it is an arrest of the normal swing to the left at a later stage of development, is accepted. We are, however, using the term in a purely descriptive sense without embryological implications: most of the hearts should be otherwise normal if this alone was the development mechanism, but this is not so.

In groups (2) and (3) there are nearly always other malformations of the heart. Rösler (1930) thought this was always so, but Lichtman (1931) in 161 reported cases found 3 where the heart was otherwise normal.

Our classification (Campbell and Deuchar, 1965) tries to allow for the fact that the atria and ventricles may be inverted independently, and makes it easy to see which types of dextrocardia are mirror-images of which types of lævocardia.

So much has been written about dextrocardia, in contrast with the relative paucity of papers on isolated lævocardia, that we cannot review the subject fully, but would refer to the papers of Korth and Schmidt (1953, 1954) and Schmidt and Korth (1954). They found that among more than 1000 cases of mirror-image inversion of the heart only 12 were without inversion of the abdominal viscera. They discussed also 97 reported cases of dextroversion and found only 6 without other malformations of the heart.

RELATIONSHIP OF THE ATRIA AND THE ABDOMINAL VISCERA

The embryological development of the right atrium,

with the absorption of the sinus venosus and the mouths of its main tributaries into the right atrium, should mean that the morphological right atrium is always the one into which the superior vena cava drains. The venous atrium might, therefore, be expected to be on the right when the abdominal veins and viscera are normally placed and on the left when they are inverted. However, nearly half our cases of isolated lævocardia and 3 of our 29 cases of dextrocardia seemed to be exceptions to this generalization.

In 1955, when Ivemark wrote on the implications of agenesis of the spleen with the tendency to symmetry of the liver, we looked on it as a curious and fascinating association. Re-reading his monograph after writing on isolated lævocardia (Campbell and Deuchar, 1965) we added a footnote about its relevance to our cases, but did not think it had made a fundamental contribution to classification. Probably this was wrong, and about the time we finished our paper, Van Praagh *et al.* (1964) reported 51 cases of dextrocardia, all with necropsies; and to the usual grouping according to the situs of the abdominal viscera (1) with normal location and (2) with situs inversus, added a third group (3) with Ivemark's asplenia syndrome and relative symmetry of the abdominal viscera. This is best shown by the liver which occupies both sides and by the lobation of the lungs; but unsatisfactorily by the stomach since this lies on one side or the other rather erratically.

The most important claim of Van Praagh *et al.* is that "the visceral situs and the atrial situs are always the same", and that they know of no exception where the viscera are inverted and the morphological right atrium is not. The many apparent exceptions among reported cases are, they think, to be explained by the asplenia syndrome with its tendency to visceral symmetry, where the true situs of the viscera may be misjudged by the position of the stomach. This would mean that isolated mirror-image dextrocardia (type II of Reinberg and Mandelstam, 1928) does not occur, a view already stressed by Rösler (1930). Before considering how the views of Van Praagh *et al.* influence our classification and cases, a little more will be added about the asplenia syndrome.

THE ASPLENIA SYNDROME

In 1934, Putscher found that 20 of 23 reported cases without a spleen had malformations of the heart, especially some degree of *situs inversus*, septal defects, transposition, and pulmonary atresia or stenosis. Polhemus and Schafer (1952) added a common A-V valve and bilateral trilobed lungs to this syndrome.

Ivemark (1955) reviewed 55 reported cases of splenic agenesis and 14 new ones from a series of necropsy records where its incidence was 1 in 584. Only 2 of these 69 were free from malformations of the heart: 97 per cent of the others had cono-truncal malformations, and 56 of the 58 with an adequate description (97%) had malformations in the region of the A-V valve, a common A-V ostium in 79 per cent (with cor biloculare in 48%). He said less about the situs of the heart, but there was dextrocardia in 23, isolated lævocardia in at least 23 of the 36 where the heart was on the left, and no record about its position in the 10 others.

Ivemark called it "asplenia; a teratologic syndrome of visceral symmetry", and emphasized the frequency with which the liver occupied both sides. It was relatively symmetrical in 31 (45%) and inverted in 17, and in many others there was no information and no clear statement that it was normal. The lobation of the lungs was symmetrical in 58 per cent, most often three lobes on each side. Total or partial anomalous pulmonary venous drainage was found in 52 per cent. There was known to be a common mesentery in 48 per cent.

The stomach was inverted in 64 per cent of those with lævocardia but in only 35 per cent of those with dextrocardia, which encouraged us to think that the relative symmetry meant incomplete forms of abdominal situs inversus with lævocardia, and of normal abdominal situs with dextrocardia.

Ivemark reported also 10 cases with multiple small spleens and with similar cardiac malformations, and thought these should be linked with the main syndrome.

Van Praagh *et al.* (1964) wrote, "the atrial situs usually remains morphologically uncertain or indeterminate in view of the following characteristic findings: deficiency or absence of the components of the atrial septum, a common atrium being frequent; common A-V valve; absence of the coronary sinus; bilateral superior venæ cavæ; and total anomalous pulmonary venous return." Van Mierop, Patterson, and Reynolds (1964) have described two interesting cases of asplenia where the two atria were almost mirror-images of each other. There was no coronary sinus, since the left sinus horn had been incorporated in the left atrium, and the right sinus horn (as usual) had been incorporated in the right atrium. There was also a sinu-atrial node in both atria. They, however, formed almost a common atrium, since the atrial septum consisted of no more than a remnant of the septum primum.

Others who have written about the asplenia syndrome since have given more details about the cardiac malformations than about the abdominal viscera. Grant (1958) stated that with dextroversion

especially there was often agenesis of the spleen and some heterotaxy of the abdominal viscera, which tended to be more primitive and bilaterally symmetrical. In our experience, however, the asplenia syndrome is not common with dextroversion (only Case 42 in our group D III and perhaps Cases 48 and 49).

Gilbert, Nishimura, and Wedum (1958) and Ruttenberg *et al.* (1964) do not give complete details about the abdominal viscera in the syndrome. The latter describe 17 cases. A liver on both sides was said to be common and there was some degree of heterotaxia of the viscera in 13 of the 17.

Van Praagh *et al.* (1964) write "the abnormally symmetric viscera often display some of the characteristics both of situs solitus and of situs inversus in the same individual", but they give few details. From the papers quoted it is hard to see whether the liver was bilateral in nearly all the cases or in about half of them, as found by Ivemark, or what other evidence there was of symmetry of the abdominal viscera.

APPLICATION TO OUR CASES

Assuming the views of Van Praagh *et al.* are in the main correct, our groups L II, L IV, D II, and D IV may consist of cases with asplenia and may need some modification as regards the situs of the abdominal viscera, which we had settled on the position of the stomach. We had no examples in L II but had 12 in the other three groups: there were 9 with isolated lævocardia (Cases 7-15, group L IV) and three with dextrocardia. The only three with necropsies did, in fact, have the asplenia syndrome. In all these three the liver occupied both sides. The spleen was absent in Cases 8 and 9 and was composed of four lobes with other small areas of splenic tissue along the splenic vessels in Case 7—a syndrome that Ivemark linked with asplenia. We have no note about the lungs in Case 7: there were 3 lobes on each side in Case 9, and 4 on the right and 3 on the left in Case 8.

Of the 6 others with lævocardia, 2 have died but had no necropsy. In Case 12 "the liver was probably on both sides", and in Case 13 "the liver may have been partly on both sides". We cannot trace 2 (Cases 10 and 14): in the former "although the liver seemed palpable on the right side, x-ray examination confirmed that the stomach was on the right and the gall-bladder on the left so probably the liver was on both sides". The inverted commas indicate quotations from Campbell and Forgacs (1953).

The last 2 with lævocardia (Cases 11 and 15) were recently examined. In both the stomach is on the

right and the liver on the left without any evidence that it is bilateral. Nor can we find any changes on blood examination to suggest asplenia, and isotope studies show there is splenic tissue at the normal site for an inverted spleen, but this cannot exclude polysplenia.

Of the 3 with dextrocardia, the liver was thought to occupy both sides in Case 31 (D II) who died but had no necropsy. In Case 48 who was re-examined recently, the blood picture showed no evidence of asplenia and the splenic scan localized a spleen, about 10 by 10 cm., below the left diaphragm. Radiological examination confirmed that the stomach was on the left and the liver was thought to be on the right, but the last film showed the diaphragm higher on the left side so possibly the liver may be bilateral. Case 49 (also D IV) is unwilling to have any special examination: the stomach is normally placed and we think the liver is also. In all these three, the normal IVC was absent.

Thus, out of these 12 cases, the only 3 with necropsies had asplenia or an abnormal spleen and a relatively symmetrical liver. There were 4 others where the liver was bilateral. In the remaining 5, we could find no evidence of the asplenia syndrome in 4 and doubtful evidence in 1, but only 3 of these 5 had special examinations for this purpose. Thus, most of our cases, including all who had necropsies, support the thesis of Van Praagh *et al.* but not on the present evidence all of them. We are less certain about the symmetry of the abdominal viscera other than the liver. It is not easy to see how the symmetry of the liver produces this effect, especially because it is normally symmetrical as late as the 63rd day (Hamilton, Boyd, and Mossman, 1962), long after these malformations have been decided.

There was fairly close agreement about the types of dextrocardia in our series and in that of Van Praagh *et al.* (1964)—with isolated dextrocardia, 51 per cent in both series; with complete situs inversus, 34 per cent in ours and 31 per cent in theirs; and with the asplenia syndrome, 14 per cent in ours and 18 per cent in theirs.

There is general agreement about the other cardiac malformations specially likely to be found with the asplenia. Our cases with partial or complete situs inversus tend to have the same malformations. Admittedly a common A-V valve and total anomalous pulmonary venous drainage were less common in our series. They are, however, lesions with a heavy mortality in infancy; and 55 per cent of our patients were 5 years old or more when they were first seen 15 years ago; and in the series of Ruttenberg *et al.*, Ivemark, and Van Praagh *et al.*, 76, 73, and 60 per cent respectively had died in their first six months.

A common atrium was more frequent in our probable cases of asplenia (36%) than in our other cases with complete or partial situs inversus (19%), and this was true for a common ventricle also.

We do not rate *bilateral superior vena cavae* (SVC) very highly as evidence of symmetry of the viscera, since they occur in at least 2 per cent of those with malformations of the heart other than situs inversus (Campbell and Deuchar, 1954), and in 0.3 per cent of over 3000 unselected cadavers (Sanders, 1946). They are, however, much more common in our present series—in 4 of 12 of our possible asplenia cases and in 24 per cent of all other cases with complete or partial situs inversus. This is about the same as the percentages found in the asplenia syndrome (28%, Ivemark, and 24%, Van Praagh *et al.*).

Bilateral SVC were present in at least 19 of Ivemark's cases, and it seems from his Tables A-D that the right SVC drained into the right, and the left into the left atrium in all of them, though he states this specifically only for 4 of his own cases. There was a bilocular heart in 9 of them and as the other 10 are recorded with an ostium primum or ostium secundum, this may sometimes have amounted to a common atrium. In our experience it is most unusual for the two SVC to drain into separate atria, and we can recollect only one such case, a patient with normal situs of the heart and viscera (Campbell and Jackson, 1953) and even here there was a large ASD. It is, however, more common, but still not the general rule, for the two SVC to drain into the two sides of a common atrium. There were two examples in this series where they did so (Cases 9 and 44).

In *conclusion*, we agree that apparent discordance of the situs of the atria and abdominal viscera occurs generally, and perhaps always, in cases with the asplenia syndrome. The cases in our groups L II, L IV, D II, and D IV are probably examples of this syndrome. Before reaching a final conclusion, we plan to write about the experimental work on the production of situs inversus in animals and its embryology in man; and how this association with asplenia and a bilateral liver fits into the picture.

SUMMARY

We have described the malformations of the heart found in 29 patients with dextrocardia, and their progress for up to 16 years. There were 10 with situs inversus, 16 with isolated dextrocardia and 3 with less usual types that are probably examples of the asplenia syndrome.

The associated malformations of the heart and the prognosis in these patients seem to be the same as in those with isolated *lævocardia*. There is a heavy mortality in infancy and early childhood; but those

who survive for 7 years often get on reasonably well, and a few who have an adequate blood supply to the lungs get on very well for 15 years and probably much longer.

The frequency of complete or partial situs inversus in those who are born without a spleen was emphasized 30 years ago. We have discussed the asplenia syndrome and its implications for our cases and our classification. We agree with Van Praagh *et al.* (1964) that most, but perhaps not all, cases where there appears to be discordance between the situs of the atria and of the abdominal viscera are examples of the asplenia syndrome and often have a liver that occupies both sides.

REFERENCES

- Berri, G. G. (1958). *Dextrocardias y Levocardias*. Talleres Graficos Didot, Luca, Buenos Aires.
- Brinton, W. D., and Campbell, M. (1953). Necropsies in some congenital diseases of the heart mainly Fallot's tetralogy. *Brit. Heart J.*, **15**, 335.
- Brown, J. W. (1950). *Congenital Heart Disease*, 2nd ed., p. 271. Staples Press, London.
- Campbell, M. (1963). The mode of inheritance of isolated lævocardia and dextrocardia and situs inversus. *Brit. Heart J.*, **25**, 803.
- , and Deuchar, D. C. (1954). The left-sided superior vena cava. *Brit. Heart J.*, **16**, 423.
- , and — (1961). Continuous murmurs in cyanotic congenital heart disease. *Brit. Heart J.*, **23**, 173.
- , and — (1965). Dextrocardia and isolated lævocardia. I: Isolated lævocardia. *Brit. Heart J.*, **27**, 69.
- , and Forgacs, P. (1953). Lævocardia with transposition of the abdominal viscera. *Brit. Heart J.*, **15**, 401.
- , and Jackson, J. W. (1953). An unusual case of cor biloculare with bilateral superior venæ cavæ. *Guy's Hosp. Rep.*, **102**, 337.
- , and MacCarthy, D. (1957). Morbus coeruleus with inversion of the abdominal viscera in two cousins. *Guy's Hosp. Rep.*, **106**, 18.
- , Reynolds, G., and Trounce, J. R. (1953). Six cases of single ventricle with pulmonary stenosis. *Guy's Hosp. Rep.*, **102**, 99. (Case 4—p. 113).
- Denolin, H. (1950). Situs inversus total avec malformation cardiaque et dissociation auriculo-ventriculaire d'origine congénitale. *Acta cardiol. (Brux.)*, **5**, 329.
- Gilbert, E. F., Nishimura, K., and Wedum, B. G. (1958). Congenital malformations of the heart associated with splenic agenesis. *Circulation*, **17**, 72.
- Grant, R. P. (1958). The syndrome of dextroversion of the heart. *Circulation*, **18**, 25.
- Hamilton, W. J., Boyd, J. D., and Mossman, H. W. (1962). *Human Embryology: Prenatal Development of Form and Function*, 3rd ed. Heffer, Cambridge.
- Ivemark, B. I. (1955). Implications of agenesis of the spleen on the pathogenesis of cono-truncus anomalies in childhood. *Acta pædiat. (Uppsala)*, Suppl. 104.
- Korth, C., and Schmidt, J. (1953). Dextroversio cordis. *Arch. Kreisl.-Forsch.*, **20**, 167.
- , and — (1954). Essentielle Dextropositio cordis. *Fortscher. Röntgenstr.*, **81**, 46.
- Lev, M., and Rowlatt, U. F. (1961). The pathologic anatomy of mixed lævocardia. *Amer. J. Cardiol.*, **8**, 216.
- Lichtman, S. S. (1931). Isolated congenital dextrocardia: report of two cases with unusual electrocardiographic findings; anatomic clinical roentgenologic and electrocardiographic studies of the cases reported in the literature. *Arch. intern. Med.*, **48**, 683.
- Nagel, M. (1909). Beiträge zur Kasuistik und Lehre von der angeborenen reinen Dextrocardie. *Dtsch. Arch. klin. Med.*, **96**, 552.
- Paltauf, R. (1901). Dextrocardie und Dextroversio cordis. *Wein. klin. Wschr.*, **14**, 1032.
- Polhemus, D. W., and Schafer, W. B. (1952). Congenital absence of the spleen: syndrome with atrioventricularis and situs inversus. *Pediatrics*, **9**, 696.
- Putzchar, W. (1934). *Die Entwicklungsstörungen der Milz*. Quoted by Ivemark (1955).
- Reinberg, S. A., and Mandelstam, M. E. (1928). On the various types of dextrocardia and their diagnostics. *Radiology*, **11**, 240.
- Rösler, H. (1930). Über die angeborene isolierte Rechtslage des Herzens. *Wien. Arch. inn. Med.*, **19**, 505.
- Ruttenberg, H. D., Neufeld, H. N., Lucas, R. V., Carey, L. S., Adams, P., Anderson, R. C., and Edwards, J. E. (1964). Syndrome of congenital cardiac disease with asplenia. *Amer. J. Cardiol.*, **13**, 387.
- Sanders, J. M. (1946). Bilateral superior venæ cavæ. *Anat. Rec.*, **94**, 657.
- Schmidt, J., and Korth, C. (1954). Die Klinik der Dextrocardien. *Arch. Kreisl.-Forsch.*, **21**, 188.
- Shaher, R. M., and Johnson, A. M. (1963). Isolated lævocardia and isolated dextrocardia: pathology and pathogenesis. *Guy's Hosp. Rep.*, **112**, 127.
- Van Mierop, L. H. S., Patterson, P. R., and Reynolds, R. W. (1964). Two cases of asplenia with isomerism of the cardiac atria and the sinoatrial nodes. *Amer. J. Cardiol.*, **13**, 407.
- Van Praagh, R., Van Praagh, Stella, Vlad, P., and Keith, J. D. (1964). Anatomic types of congenital dextrocardia; diagnostic and embryologic implications. *Amer. J. Cardiol.*, **13**, 510.