Left Ventricular Angiocardiography in Atrioventricular Defects

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The variation in the pathological anatomy of atrioventricular defects influences presentation, prognosis, and the results of surgical treatment. In particular the structure and function of the mitral valve have an important bearing on the success of surgical correction of the deformed valve. The purpose of this paper is to indicate the value of left ventricular angiocardiography in assessing the complete anatomy of the atrioventricular defect and in distinguishing those patients who are likely to do well with surgical correction. The accuracy of left ventricular angiography in differentiating atrioventricular defects from similar lesions has also been examined.

TERMINOLOGY

The term "atrioventricular defect" has been used to describe the whole group of lesions which include ostium primum atrial septal defect, complete common atrioventricular canal, and true single atrium (Somerville, 1965, 1966a). The diagnosis of ostium primum was accepted when there was no evidence of a functioning ventricular septal defect on angiocardiography (see below). Common atrioventricular canal was diagnosed when contrast medium was seen to pass direct from the left ventricle to the right ventricle, demonstrating a ventricular septal defect beneath the atrioventricular valves. The diagnosis of single atrium was made when no evidence of an atrial septum was found at catheterization and angiocardiography. Patients with the transitional form of atrioventricular defect, namely an ostium primum with cleft mitral and tricuspid valves and a depression of the upper border of the ventricular septum, were included in the group of ostium primum. This was because none of the patients had a functioning ventricular septal defect and so behaved clinically like an ostium primum and could not be separated from ostium primum by angiocardiography.

SUBJECTS AND METHODS

Forty-two patients with atrioventricular defects were investigated by left ventricular angiocardiography

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(Group 1). In this group 24 were male and 18 were female, between the ages of 3 months and 38 years; the diagnosis of atrioventricular defect was confirmed by open-heart surgery, or necropsy, or both, in 27 patients, and in the other 15 was accepted from the combined clinical, electrocardiographic, and angiocardiographic findings. Of the atrioventricular defects, ostium primum defect was present in 28, common atrioventricular canal in 12, and single atrium in 2. A further 10 patients, in whom there were some clinical and electrocardiographic features such as left axis deviation suggesting an atrioventricular defect, had left ventricular angiocardiograms (Group 2). Atrioventricular defects were not found in any of the patients in Group 2 and the lesions discovered at operation or necropsy were secundum atrial septal defect in 4, ventricular septal defect in 3, ventricular septal defect with pulmonary stenosis (Fallot) in 2, and tricuspid atresia with large ventricular septal defect in one.

Routine cardiac catheterization was carried out in each patient before angiocardiography. In children, after the haemodynamic study, the Courmand catheter was replaced by the largest possible N.I.H. catheter which was passed from saphenous vein into the left ventricle via the right atrium, atrial septal defect, and mitral valve. In view of this easy access to the left ventricle, the arterial route was not used in children for fear of permanent arterial damage, but in adults a right brachial arteriotomy was performed and the catheter passed across the aortic valve into the left ventricle. The tip of the catheter was directed towards the apex of the left ventricle to prevent interference with the mitral valve. Conray 420 in doses of 1-2 ml. per kg. body weight was injected at a pressure of 8-4 kg. per sq. cm., and biplane Elema roll films were exposed in the frontal (anterior) and lateral planes at 6 films a second.

The anatomy of the atrioventricular defect was inspected by one of us (J.S.) at open operation. The degree of mitral regurgitation was assessed by the surgeon. Particular attention was paid to the presence of deficient cusp tissue and tethering of the anterior cusp of the mitral valve by short or abnormal tendinous insertion and papillary muscles. When the cusps remained slanting down in the body of the left ventricle during systole, the valve was considered to be relatively immobile.

FIG. 1.—Diagram to show the attachment of the anterior cusp of the mitral valve in the normal and patients with atrioventricular defects.

In contrast the mitral valve was thought to be mobile when the anterior cusp billowed up in systole.

The anatomy of the mitral valve and degree of mitral regurgitation were assessed from the left ventricular angiocardigrams and correlated with the operative findings and post-operative mitral regurgitation.

The degree of post-operative mitral regurgitation was assessed clinically. Severe mitral regurgitation was accepted if pulmonary oedema developed or if there was an obvious clinical and electrocardiographic enlargement of the left ventricle within 6 months of operation. The presence of a pansystolic murmur without increasing left ventricular enlargement was considered to represent only a mild degree of mitral regurgitation.

ANATOMICAL CONSIDERATIONS

The anterior cusp of the mitral valve in the normal person should be considered as having three attachments: (1) aortic, to the base of the non-coronary and left coronary cusps, (2) free wall, to a short area of the lateral free wall of the left ventricle, (3) septal, to the posterior border of the atrioventricular septum (Fig. 1). In the frontal view of a normal left ventricular angiocardigram the upper medial border is formed by the atrioventricular septum and the lower medial border by the muscular ventricular septum (Fig. 2a and b).

In atrioventricular defects, the atrioventricular septum fails to develop, probably owing to the failure of the endocardial cushions to arch upwards (Van Mierop *et al.*, 1962). The anterior cusp of the mitral valve which normally would be attached to the posterior part of the atrioventricular septum is displaced downwards to lie at the

same level as the septal cusp of the tricuspid valve. This results in disturbance of the septal attachment of the anterior cusp which in atrioventricular defects originates from the crest of the ventricular septum. The superior (or anterior) portion projects abnormally into the left ventricular outflow tract, and the upper part may extend over as far as beneath the commissure between the right coronary and non-coronary aortic cusps. This encroachment into the outflow tract gives rise to the waisted or "goose neck" appearance on angiocardiology, which becomes most marked in diastole when the superior part of the anterior cusp in the open position further "invades" the outflow tract. Since the anterior cusp has an unusually long attachment along the whole crescentic upper border of ventricular septum and lies in the sagittal plane, it appears on the frontal projection of the left ventricular angiocardigram as an irregular contour on the medial border of the left ventricle. Irregularity is related to the presence of aberrant short chordae running on to the ventricular septum and to redundant valve cusp tissue.

Since the cleft anterior mitral cusp is rotated forwards to lie almost in the sagittal plane, it does not form the posterior border of left ventricular outflow tract in the lateral view, and the diastolic carrot-shaped outflow tract frequently seen in the lateral angiocardigram when the mitral valve is normally attached (Fig. 3) is never seen in atrioventricular defects. The abnormal plane of the mitral valve causes it to appear in diastole as a window in the upper part of the left ventricle, viewed laterally, when blood not containing opaque dye flows through the mitral valve into the opacified left ventricle.

The short aortic and free wall attachments of the

FIG. 2.—Left ventricular angiogram in the frontal plane from a patient with secundum atrial septal defect and left axis deviation showing normal atrioventricular septum in (a) systole and (b) diastole.

FIG. 3.—Lateral view of left ventricular angiogram in diastole from patient with secundum atrial septal defect showing anterior cusp of the mitral valve (arrow) forming the posterior border of the outflow tract and typical carrot-shaped opacity.

anterior mitral cusp are normal in atrioventricular defects. The posterior cusp also has a normal attachment, though the cusp may be smaller and slightly thicker than normal and it is seen as a curved line on the posterior wall of the left ventricle in the frontal angiogram as in the normal (Baron *et al.*, 1964).

RESULTS

With these anatomical considerations in mind, angiographic features have been examined under the following headings.

Group 1 (42 patients with atrioventricular defects).

(1) *Right (medial) border of left ventricle on frontal left ventricular angiogram.* In the 42 patients there was no evidence of the normal smooth atrioventricular septum in the upper part of the medial border of the left ventricle. This was replaced in systole by a crenated contour due to the abnormally displaced superior portion of the anterior mitral cusp (Fig. 4a).

Further down, the medial border was also formed by anterior cusp (inferior portion), frequently crenated and moving during the cardiac cycle. The lowest, most medial part of the left ventricle was pointed in 26 patients as the result of contrast being trapped beneath the mitral cusp and ventricular septum.

In 14 patients there was scalloping of this border in systole, producing multiple convex bulges to the right which usually disappeared in diastole (Fig. 4a and b). Other patients had small crenations which

FIG.4.—Frontal view of left ventricular angiogram in a patient with an atrioventricular defect in (a) systole and (b) diastole. The medial border of the left ventricle is formed by the anterior cusp of the mitral valve and appears as an irregular scalloped edge. The superior portion of the anterior cusp of the mitral valve, indicated by the arrow, changes position during the cardiac cycle, becoming more horizontal in diastole.

FIG.5.—Double mitral valve (a) diagram of surgeon's (D.N.R.) view of the mitral valve; (b) frontal view of left ventricular angiogram in systole showing double row of irregularities along medial border of the left ventricle.

FIG. 6.—Left ventricular angiogram (frontal view) showing unusually gross scalloping on the medial border from a patient with ostium primum defect, and redundant cusp tissue attached to the edge of the defect.

persisted in diastole as well as in systole, and in some the whole border remained concave in all phases of the cardiac cycle (see below Fig. 7).

In two patients there appeared to be two rows of fine irregularities in the region of the medial border and both patients were found to have a double mitral valve at operation (Fig. 5a and b). One other

patient had redundant cusp tissue attached to the whole edge of and filling the ostium primum defect as well as the usual cleft anterior cusp. Unusually gross scalloping of the central portion of the medial border was seen in this patient (Fig. 6).

(2) *Visibility of cleft in anterior cusp shown on medial left ventricular border in frontal angiogram.* A V-shaped indentation was observed on the medial border of the left ventricle during systole in 9 patients. This was considered to represent the cleft in the anterior cusp of the mitral valve (Baron *et al.*, 1964). When small jets of mitral regurgitation were present they were usually seen to originate in this V-shaped area which corresponded to the region of the apex of the cleft at the time of inspection at operation. The cusps bordering the cleft were found to be thickened at operation.

(3) *Appearance of left ventricular outflow tract in frontal plane.* The left ventricular outflow tract varied in size and position during the cardiac cycle. In diastole the superior part of the anterior cusp of the mitral valve tended to become further displaced into the left ventricular outflow tract so that the outflow appeared to be narrower and more horizontal than during systole (Fig. 4). The crenations apparent on the medial surface of the outflow tract in systole disappeared in diastole as the cusp straightened out in the open position and appeared as a straight or slightly curved border crossing the outflow tract. In 9 patients (6 with ostium primum, 2 with common canal, 1 with single atrium), the outflow tract was narrow in systole and diastole, and

FIG. 7.—Left ventricular angiogram (frontal view) from a patient with immobile anterior cusp who died of mitral stenosis following suture of the cleft at operation: (a) systole; (b) diastole.

in 6 of these there was little or no change in the shape of the outflow during the cardiac cycle (Fig. 7). In 3 there was a change in configuration of the outflow tract in spite of narrowing throughout the cardiac cycle (Fig. 8). The problem of cusp movement has been elaborated below in the section on "mobility of the mitral valve".

(4) *Left ventricular outflow tract in lateral view.* In the lateral projection, the anterior cusp of the mitral valve did not form the posterior border of the left ventricular outflow tract in any of the 42 cases, and the diastolic carrot-shaped outflow tract was never seen. The mitral valve often appeared *en face* as a fenestrated window within the upper posterior part of the left ventricle in diastole. The anterior border of the left ventricular outflow tract was formed by the muscular ventricular septum, and abnormal short chordae attaching the edge of the anterior mitral cusp to the ventricular septum often produced an irregularity. This was noted in 11 of our cases, and in 2 an irregular diverticulum-like structure arose from this border beneath the anterior cusp of the mitral valve and was interpreted as being due to medium caught in between the aberrant chordae and cusp tissue of the cleft mitral valve (Fig. 9). This was confirmed in 6 patients who had operation.

(5) *Mitral regurgitation—direction of jet and degree of regurgitation.* In 3 patients there was no evidence of mitral regurgitation in spite of passage of the catheter across the mitral valve, and this correlated with clinical absence of a pansystolic murmur.

FIG. 9.—Left ventricular angiogram (lateral view) showing irregularity in the anterior portion of outflow tract where dye passes between short chordae under the anterior cusp of the mitral valve.

Thirty-nine patients had some mitral regurgitation which varied from trivial and localized to gross and diffuse. The jet of mitral regurgitation was commonly directed anteriorly and laterally towards the right atrium giving the spurious appearance of a

FIG. 8.—Left ventricular angiogram (frontal view) from a patient with a partially mobile anterior cusp and tethering of the upper part of the superior portion at operation: (a) systole, (b) diastole.

FIG. 10.—Left ventricular angiogram (lateral view) showing jet of mitral regurgitation mimicking a ventricular septal defect. (a) Jet passes anteriorly; (b) next frame shows filling of right atrium. At operation a simple ostium primum and cleft mitral valve were found with no evidence of ventricular component of the defect.

ventricular septal defect on the lateral angiogram (Fig. 10). Successive lateral films showed that the right atrium quickly became opacified by this jet before the right ventricle was outlined. This frequently resulted in dense opacification of the lower part of the right atrium on the frontal view as the mitral regurgitant jet was directed through the ostium primum defect. The right atrium was usually opacified more densely than the left atrium in all forms of atrioventricular defect. In patients where mitral regurgitation was severe, there was regurgitation back into the left atrium as well as towards the lower part of the right atrium so that both atria filled simultaneously. In one patient the left atrium was densely opacified before the right. This was in a child who was found at operation to have an unusually small ostium primum with bad mitral regurgitation, and the jet of mitral regurgitation was directed towards the right side of the left atrium but not posteriorly as in other forms of mitral regurgitation.

Angiocardiographic assessment of the degree of mitral regurgitation in 39 patients showed that it was trivial in 14, moderate in 13, and severe in 12. The incidence of mild, moderate, and severe mitral regurgitation was the same with each type of atrioventricular defect. The presence of trivial or absent

mitral regurgitation correlated with pre-operative clinical and operative findings. Clinically, it was difficult to distinguish between moderate and severe mitral regurgitation, but there was correlation between angiocardiographic and surgical findings with about 70 per cent agreement.

(6) *Filling defects due to abnormal papillary muscles and tendinous insertions.* In 5 patients persistent filling defects were noted in anterior or lateral views and were considered to be due to abnormally formed papillary muscles which were unusually broad. This was confirmed in 2 of these patients who had come to necropsy; each revealed a thick short papillary muscle with an unusually short tendinous insertion (Fig. 11a).

(7) *Angiocardiographic evidence of mobility of mitral valve related to degree of mitral regurgitation and post-operative mitral regurgitation.* Since the anterior cusp of the mitral valve forms the medial border of the left ventricle, movement of this border has been considered to reflect mobility of this cusp which makes up the major portion of the valve. The larger superior portion of the cleft cusp borders the left ventricular outflow tract so that changing shape and position of the outflow are related to movement of this part of the cusp.

The presence of a mobile or an immobile anterior

(a)

(b)

(c)

FIG. 11.—Immobile mitral valve in patient with single atrium. (a) Undersurface of the mitral valve. Upper arrow shows abnormal papillary muscle inserting into and anchoring superior portion of the anterior cusp. Lower arrow shows gap of 1 cm. between the two parts of the anterior cusp (c) which is deficient and thickened. (b) Left ventricular angiogram (frontal view) in systole, showing marked narrowing of the outflow tract (upper arrow). Lower arrow shows site of mitral regurgitation which was severe. (c) Diastole: narrowing of left ventricular outflow tract with no movement of superior portion of anterior cusp (left arrow). Filling defect in upper part of outflow (upper right arrow) due to grossly deformed aberrant papillary muscle.

TABLE
MOBILITY OF MITRAL VALVE AND POST-OPERATIVE
RESULTS IN 26 PATIENTS

Anterior cusp of mitral valve	No *	Pre-operative mitral regurgitation			Post-operative regurgitation or stenosis†
		—	++	+++	
Immobile	4	0	1	3	4 (3)
Mobile	21	11	8	2	0 (0)

* 2 patients with double mitral valve are not included.

† Figures in parentheses indicate number who died.

++ Moderate mitral regurgitation.

+++ Severe mitral regurgitation.

cusps on the left ventricular angiogram has been correlated with the degree of mitral regurgitation pre- and post-operatively (Table) in 26 patients who had surgery. Four patients with a relatively immobile valve (Fig. 5) had severe mitral problems after operation and 3 of these died in low output states or with pulmonary oedema. The survivor is awaiting mitral valve repair as he has all the signs and symptoms of severe mitral regurgitation. One further patient with angiocardiographic evidence of an immobile anterior mitral cusp (Fig. 11b and c) died at home. Necropsy confirmed the clinical diagnosis of single atrium and showed considerable

FIG. 12.—Left ventricular angiogram (lateral view) from a patient with common atrioventricular canal proven at operation. Upper arrow shows jet passing into right ventricle through ventricular septal defect. Lower arrow shows small jet of mitral regurgitation which passed into right atrium.

deficiency of anterior cusp tissue, with a distance of 1 cm. between the two parts of the anterior cusp in the region of the apex of the cleft as well as a thick abnormal anterior papillary muscle inserting directly into the cusp and rendering it relatively immobile (Fig. 11a). Two of the three patients who had some mobility of the superior portion of the anterior cusp and narrowing of the outflow tract in systole and diastole (Fig. 8) had operation. Both had adequate anterior cusp tissue which was mobile near the free edge and fixed in the upper part of the superior portion. The mitral regurgitation lessened but was not completely abolished by surgery.

None of the 21 patients with a mobile valve on the angiogram had any problems from mitral regurgitation or stenosis after operation. Trivial or absent mitral regurgitation was usually found with a mobile valve. Although severe mitral regurgitation was sometimes associated with a mobile valve, it was commoner in those with immobile valves.

The presence of severe mitral regurgitation did not preclude a good surgical result, provided the anterior cusp was mobile.

(8) *Diagnosis of type of atrial septal defect.* In all the patients who had reflux of contrast medium through the mitral valve, the lower part of the right atrium filled through the ostium primum defect. In 6 patients, contrast medium crossed the upper part of the atrial septum as well as the lower part; this was considered to suggest the presence of an additional secundum defect which was confirmed in the 3 of this group who had operations. In both patients with single atrium, there was no sign of atrial septum when free reflux of contrast medium revealed a common chamber; the diagnosis was confirmed in both. (9) *Diagnosis of ventricular component of atrio-ventricular defect.* The diagnosis of common atrio-ventricular canal depended on the demonstration of a ventricular component in the defect. Contrast medium in the lateral plane passing directly from left ventricle to right ventricle, through a ventricular septal defect, was seen in 12 patients (Fig. 12). Common atrioventricular canal was confirmed in 3 patients at operation but no operation was undertaken in the rest because of pulmonary vascular disease. The clinical and haemodynamic findings in these supported the diagnosis of common atrio-ventricular canal. In 5 patients considered to have common atrioventricular canal there were two jets of contrast passing forwards from the left ventricle in the lateral view (Fig. 12). Scrutiny of the corresponding frontal view showed that one was due to mitral regurgitation as the right atrium filled, and the other was directed into the right ventricular outflow tract through the ventricular component of the defect. When functioning ventricular septal defect

was present, the medial border of the left ventricular outflow tract was frequently obscured in the frontal plane, and mobility of the superior portion of the anterior cusp was more difficult to judge in common atrioventricular canal than in patients with ostium primum defect and single atrium. In two patients with common canal who had been banded in infancy another jet of contrast medium was seen to pass across the ventricles close to the apex. This was interpreted as evidence of an additional ventricular septal defect in the muscular septum and has been discussed elsewhere (Somerville *et al.*, 1967). No ventricular component of the defect was demonstrated in the two patients who were found at operation to have the transitional form of atrioventricular defect with both cleft mitral and tricuspid septal leaflets.

(10) *Pathological anatomy of tricuspid valve.* Left ventricular angiography gave no indication of the presence or absence of abnormality of the septal cusp of the tricuspid valve even when there was a direct left ventricular-right ventricular shunt as in true common atrioventricular canal.

Group 2 (10 patients with septal defects other than atrioventricular defects).

The left ventricular outflow tract was normal in the 10 patients (Fig. 2a and b). The right medial border of the left ventricle was not formed by the mitral valve in any patient and there was unequivocal evidence of the normal atrioventricular septum. The anterior cusp of the mitral valve was seen to form the posterior border of the left ventricular outflow tract in each patient and the "diastolic carot" was evident in 6 patients: this sign was less obvious in children than in adults (Fig. 3). In the patients with secundum atrial septal defect, the ventricular septum was rotated to lie in the coronal plane as the result of right ventricular dilatation, but there was no evidence of deformity of the left ventricular outflow tract. Trivial mitral regurgitation occurred in 2 patients at the beginning of the injection of contrast medium.

DISCUSSION

The left ventricular angiocardiology in the patients with atrioventricular defects constantly showed the deformity of the outflow tract and medial border that was described by Baron *et al.* (1964). This appeared in all forms of the defect but was not seen in other lesions with left axis deviation which closely mimicked atrioventricular defects in clinical presentation. Since the electrocardiogram can be atypical in 8 per cent of patients with ostium primum

and 3 per cent of common atrioventricular canal (Somerville, 1966b), left ventricular angiocardiology must be considered as the only constantly reliable method for the diagnosis of atrioventricular defect. When an atrioventricular defect is associated with transposition of the great arteries, the usual outflow tract deformity is not recognizable on the angiocardiology as the mitral valve is abnormally placed in the presence of transposition.

We have found that the left ventricular outflow tract on the angiocardiology is usually normal in the "canal" type of ventricular septal defect and intact atrial septum (Neufeld *et al.*, 1961) as well as in patients with isolated mitral regurgitation due to cleft anterior or posterior cusp. This emphasizes the difference between the lesions included as atrioventricular defects and those with other abnormalities that result from defective endocardial cushion development, and provides further support for separate classification.

The direction of the jet of mitral regurgitation in atrioventricular defects is primarily to the right and anteriorly (Somerville, 1966a, b; Rastelli, Kirklin, and Kincaid, 1967), which differs from the appearance in rheumatic mitral valve disease. This occurs because the mitral valve lies almost in the sagittal plane and the regurgitant jet usually arises at or close to the apex of the cleft in the anterior cusp near to the centre of the heart. This antero-lateral jet in the lateral angiocardiology must not be interpreted as evidence of a ventricular septal defect. Diagnosis of a ventricular component of the defect or separate ventricular septal defect can only be made when contrast medium passes from left ventricle to right ventricle usually in the region of the outflow tract with early opacification of the outflow and main pulmonary artery before the right atrium. Mitral regurgitation is often present in patients with common atrioventricular canal, and the two closely placed jets add to the problems of diagnosing the ventricular component of the defect. Right ventricular angiocardiology confirmed the presence of ventricular septal defect in four patients with high right ventricular pressure and a right-to-left shunt; contrary to the experience of Rastelli and his colleagues, we believe this investigation should be done in addition to left ventricular angiocardiology when a ventricular septal defect is suspected.

Left ventricular angiocardiology only assisted in the diagnosis of single atrium or additional atrial septal defects if there was enough regurgitation of opaque dye to fill the atrium and outline the septum or demonstrate its absence. Separate left atrial injection is considered to be obligatory for the confirmation of these lesions. We did not find angiocardiology was reliable for the diagnosis of

tricuspid valve abnormality, which is contrary to the experience of others (Omeri *et al.*, 1965).

The anatomy of the mitral valve has been found to be an important factor in the outcome of surgical treatment in atrioventricular defects. Severe post-operative mitral regurgitation is a disaster particularly in those patients who have no symptoms or only trivial disability before operation. The outcome of surgery in part depends upon what the surgeon does to the mitral valve, but accepting he does the best, which is usually only a little mobilization and suturing close to the apex of the cleft or nothing at all, there is still a group of patients who pose a difficult problem with regard to restoring normal function to the mitral valve. The main risk is in patients with relative immobility of the anterior cusp which results from a combination of such factors as cusp deficiency, tethering of superior portion of the anterior cusp, short chordal insertions, and abnormal papillary muscles. The surgeon can do little to correct the regurgitation, and suturing of the cleft has produced mitral stenosis in such patients. Observation of the changing configuration of the left ventricular outflow tract has been found to be a reliable method of assessing mobility of the superior portion of the anterior cusp. Furthermore, convexity of the medial border of the left ventricle in systole suggests an adequate amount of billowing mitral valve tissue. Patients with a narrow outflow tract in systole and diastole with little or no change in excursion between systole and diastole are considered to be in grave risk of developing post-operative mitral problems. This is the type of valve which Frater (1965) has suggested may require replacement or pericardial repair. At the present time, we feel that such patients should not be put forward for closure of the atrioventricular defect unless their symptoms demand urgent help and the risks of replacement are justified. In contrast, patients with mobility of the anterior cusp reflected by changing shape of the outflow tract and ballooning of the medial border of the left ventricle have done well and have not had more than trivial mitral regurgitation post-operatively. At open operation the mitral cusps have been seen to be adequate, sometimes voluminous and able to bulge up in systole in spite of localized areas of mitral regurgitation. In some patients, there is a change in the outflow tract during the cardiac cycle and narrowing in systole as well as in diastole. In such patients, the cusp tissue has been found to be adequate but there is some localized short tendinous insertion or tethering of the anterior cusp edge to the crest of the ventricular septum. It was possible in two patients with this appearance to obtain a good but not perfect surgical result, with lessening of the

mitral regurgitation, when Frater's suggestions about mobilization and apposition of the "kissing edges" of the split cusp were followed.

Absent or trivial mitral regurgitation on the angiogram was usually associated with a mobile type of mitral valve with adequate cusp tissue. However, severe mitral regurgitation by clinical and radiological standards was occasionally present with a mobile valve. Thus, the signs of florid mitral regurgitation did not preclude a good surgical result. Moderate or severe regurgitation was usually found with an immobile valve, with two exceptions. These patients had trivial mitral regurgitation with almost complete valvar immobility on the angiogram, and on inspection at operation both were found to have double mitral valve. The left ventricular angiogram in each showed a long, convex, relatively immobile right border with two rows of crenations (Fig. 5). This appearance may suggest the presence of a double valve. Such patients with mild regurgitation should do well after an operation. The severity of mitral regurgitation, judged clinically and radiologically, is not the most important factor in determining the likelihood of post-operative mitral problems.

The angiocardigraphic features of the mitral valve applied to all forms of atrioventricular defect (Baron *et al.*, 1964). The incidence of mobile anterior cusp was the same in ostium primum defect as in the more severe common atrioventricular canal. As a mobile valve is so often associated with trivial mitral regurgitation, this correlated with clinical assessment, which has shown that absent or trivial mitral regurgitation is as frequent in common canal as other forms of atrioventricular defect (Somerville, 1966b). Once the problems of pulmonary vascular disease are prevented by banding of the pulmonary artery, some patients with true common atrioventricular canal may be repaired with low risk. In single atrium, the problems of the mitral valve are the same as in other forms of atrioventricular defect, and criteria for selection for operation are the same.

The diagnosis of the deformity of the left ventricle and its outflow tract depend upon perfect definition. The outflow tract cannot be adequately visualized in the frontal plane if the left atrium is densely opacified, since the medial border may be obscured. If the catheter tip jumps out of the ventricle, as can easily occur in this lesion, the investigation should be repeated. Similarly, in the rare case of small ostium primum and severe mitral regurgitation, the densely filled left atrium may make delineation of the medial left ventricular borders difficult. Two angiocardigraphic views are necessary for investigation of these lesions, the frontal plane for the outflow tract and the lateral for the ventricular septal

defect. It is considered that routine left ventricular angiocardiology is an essential investigation for the assessment of all patients with atrioventricular defect.

Using the venous route to the left ventricle has been a deliberate policy, and unlike Omeri *et al.* (1965) we did not find this interfered with assessment of mitral valve anatomy. Larger catheters, No. 7 or 8 N.I.H., can be more easily introduced on the venous side than on the arterial side and this allows rapid injections of contrast medium. Success of this investigation depends on clear definition of the anatomy, which we find is only obtainable if an adequate dose of medium is rapidly given. The regurgitation sometimes produced by the catheter through the valve does not interfere with visualization of the anatomy of the mitral valve or the type of atrioventricular defect. It is considered that the advantages of using large catheters in the saphenous vein without fear of arterial damage outweigh the minor problems of producing mitral regurgitation with the catheter. Biplane Elema roll film angiocardiology was used in preference to cine-angiocardiology because first-class anatomical definition in two planes was required; but the value of cine-angiocardiology, as a supplementary examination, is being investigated.

SUMMARY

Left ventricular angiocardiology in the frontal and lateral planes have been performed in 42 patients with atrioventricular defects and 10 patients with other septal defects and left axis deviation. The exact anatomical diagnosis was proven in 27 with atrioventricular defects and in the 10 with other lesions.

Evidence of an abnormally attached mitral valve was always present in the patients with atrioventricular defects and enabled them to be distinguished from other lesions which mimicked them in presentation.

Mobility of the anterior cusp of the mitral valve can be determined from changes in shape and direc-

tion of the medial left ventricular border during the cardiac cycle. Immobility of the cusp was usually associated with a combination of factors such as deficient cusp tissue and tethering by short chordae or abnormal papillary muscles.

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