Diagnosis of Mitral Regurgitation by Cardioangiography

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To determine the feasibility of demonstrating mitral regurgitation by injection of contrast media into the left ventricle, percutaneous and subxiphoid left ventricular punctures were carried out in dogs and subsequently in human beings. Contrast media were injected and roentgenographic studies made. The correlation between the roentgenographic and subsequent anatomic findings at operation or autopsy is emphasized. The method appears to be relatively safe if proper safeguards are observed. The results indicate that the method is of value in determining the competence of the mitral valve and relative degree of insufficiency.

The surgical treatment of pure mitral stenosis has proved a sound procedure for the relief of the symptoms produced by rheumatic valvular disease. However, mitral insufficiency still presents a serious problem in its management and no adequate surgical procedures are available for the correction of this condition at the present time. Until an adequate method has been evolved for the correction of mitral insufficiency, a more accurate method should be available for the preoperative differentiation of mitral insufficiency and stenosis. A large number of patients are undergoing exploratory thoracotomy and cardiotomy with a diagnosis of mitral stenosis who are found to have predominate insufficiency; on the other hand, an operation that might benefit patients with mitral stenosis is being withheld on the basis of various clinical impressions that would indicate the presence of mitral insufficiency.

If satisfactory operations are developed for the correction of mitral regurgitation, a clinical method that gives accurate preoperative information concerning the function of the mitral valve will still be desirable. Any method that provides a more accurate preoperative diagnosis should reduce operative mortality and morbidity. Moreover, objective follow-up of patients after surgery demands accurate evaluation of this important function of the valve.

Recent attempts have been made to determine the degree of mitral insufficiency and stenosis by the use of angiocardiography. Because of the large size of the left atrium in patients with mitral disease, however, contrast dilution and retention in this chamber ordinarily prevents adequate visualization of the atrial reflux during systole. The limitations of angiocardiography in evaluating lesions of the mitral valve have been well outlined by Soloff and associates.1 The shortcomings of other presently advocated clinical methods to assess mitral regurgitation have recently been discussed by Radner.2 The importance of having such a method available has been stressed by Kent and co-workers.3

Selective angiocardiography and cardioangiography as practiced by Kjellberg4 and Lind5 have been shown to be of great diagnostic value in congenital heart disease. These investigators injected contrast media into the great vessels and various chambers of the heart through an intravascular catheter extending from one of the extremities to the heart.

More recently, Björk6 injected contrast media through a needle inserted into the left atrium from the back and made rapid serial x-ray exposures to study the mitral valve. In a case of mitral regurgitation it was possible to demonstrate lack of closure of the valve cusps during ventricular systole. The size of the needle was limited because of the tendency
for the punctured atrium to bleed. He did not recommend this procedure for clinical use.

**MATERIALS AND METHOD**

Percutaneous puncture of the right or left ventricle of the heart with the introduction of contrast media has been reported previously.7-9 The injection equipment consists of a 5\(\frac{1}{2}\)-inch, 15-gage short-beveled needle attached to a 30 ml. syringe containing 20 to 30 ml of 70 per cent Diodrast. The patient is placed supine on the x-ray table and the left side raised obliquely 50 to 90 degrees, so that the left ventricle clears the spine in the radiograph. Under local anesthesia a subxiphoid puncture of the left ventricle is accomplished. Left ventricular pressures are recorded and rapid manual injection of the contrast medium is made. Serial 2/sec. radiographs are taken with the Fairchild camera during the period just following this injection.

The details of this method and its dangers and safeguards have been reported previously. In the original study it was noted that contrast media did not regurgitate through a competent mitral valve in the dog. This observation was verified again at this time by carrying out an acute experiment in 2 additional dogs.

With positive pressure intratracheal anesthesia and open thoracotomy the dog’s heart was exposed. Pressures were obtained in the left atrium simultaneously with the electrocardiogram. A 17-gage needle was then inserted into the left ventricle through the subxiphoid approach and 10 ml of 70 per cent Diodrast was rapidly injected. Radiographs at 2/sec. were obtained during injection. A competent mitral valve was demonstrated (fig. 1), none of the contrast medium appearing in the left atrium.

By a blind technic the mitral valve was then injured to permit mitral regurgitation. Leakage of the valve was evidenced by the appearance of a thrill over the left atrium and a rise in the left atrial pressure with a characteristic change in the left atrial pressure curve. The left ventricular injection was then repeated and marked regurgitation of the contrast medium resulted through the mitral valve (fig. 2) with opacification of the left atrium and the adjacent pulmonary veins. This dog was sacrificed and the heart examined to determine the extent of the injury to the mitral valve. An 8 mm. laceration was present in the free edge of the septal cusp about 1 cm. from the posteromedial commissure.

The same procedure was carried out in a second dog but the mitral valve was less extensively injured. Here a 2 mm. laceration of the free edge of the posterior portion of the mural cusp was produced. Cardioangiography revealed a competent valve before laceration and moderate regurgitation through the lacerated incompetent valve.

The observance of mitral regurgitation by percutaneous cardioangiography has been reported previously.10, 11 Any degree of opacification in the

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**Fig. 1 and 2. Left.** Normal cardioangiogram in dog. Competent mitral valve demonstrated by absence of opacification of left atrium. The small needle is in the left atrium for pressure determination and the large needle is in the left ventricle for the injection of the Diodrast. **Right.** Cardioangiogram in same dog after surgical laceration of the mitral valve. Note the severe regurgitation into the left atrium and the pulmonary veins.
Fig. 3. Intravenous angiocardiogram in the left anterior oblique projection in a patient with a normal mitral valve. Contrast medium can be seen in the left atrium, the left ventricle, and the aorta. Note the relationship of the left atrium to the aorta and the left main-stem bronchus.

Fig. 4. A sagittal section through the mitral and aortic valves of the normal human heart in the left anterior oblique plane demonstrates the position of the left atrium in relation to the mitral valve, the aorta, and the aortic valve. Note the relationship of the septal cusp of the mitral valve to the aortic outflow tract.

The region of the left atrium immediately after left ventricular injection is considered evidence of mitral regurgitation. The amount of insufficiency may be estimated by the degree of atrial opacification provided other variables are taken into account. These variables include the quality of the films, the size of the left ventricle and the left atrium, the amount and density of the contrast medium injected, and the length of time of the injection.

To interpret correctly the radiographs obtained by this method it is important to know the anatomic relationships of the mitral valve in the left anterior oblique projection (actually the right posterior oblique projection). Figure 3 represents a conventional angiocardiogram taken with the patient in this position. In this thin adult, 50 ml. of 70 per cent Diodrast was injected rapidly intravenously and serial radiographs were taken. This radiograph was chosen from the series because it best demonstrates the relationships of the mitral valve in the left anterior oblique (right posterior oblique) view.

A normal human heart was removed at autopsy, and the chambers were filled with paraffin wax to prevent their collapse during sectioning. Sagittal sections were made in the left anterior oblique plane. A sagittal section in this plane through the mitral and aortic valves demonstrates the relationships between the atrial chamber, the mitral valve, the ventricular cavity, the ventricular out-flow tract, and the aortic valve (fig. 4).

The mitral valve was studied in 20 cases undergoing cardioangiography.

**Results**

In 10 of the 20 cases the mitral valve was found at cardioangiography to be entirely competent (fig. 5). In these cases no opacification was seen in the region of the left atrium in any of the serial radiographs. An important landmark in this right posterior oblique projection is the left main-stem bronchus, which should mark the superior border of the left atrium.

The opportunity to check the competence of the mitral valve anatomically in these 10 patients has thus far presented itself twice. One patient died because of degeneration of a homo-
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Fig. 6. Cardioangiogram of R. C. Minimal (1 plus) regurgitation through the mitral valve. A. Ventricle beginning to fill with contrast medium. B. Later film in series showing minimal opacification in region of left atrium (compare with A).

Fig. 7. Cardioangiogram of F. W. Three-plus mitral regurgitation. Note the huge size of the left ventricle and the left atrium.

graft inserted for correction of coarctation of the aorta. A resulting dissecting aneurysm finally ruptured 1 year after cardioangiography and 2 years after the placing of the graft. At autopsy, the mitral valve leaflets were normal and there was no dilatation of the valve ring. This valve was competent, confirming the previous cardioangiographic findings.

In the second case the cardioangiographic findings were not in agreement with the subsequent operative report. A competent mitral valve was apparent in the cardioangiogram; yet the operating surgeon recorded 2-plus mitral regurgitation in addition to the mitral stenosis that was present. The reason for this discrepancy is not yet certain, but it represents the only case encountered thus far of the disparity between the anatomic findings and the cardioangiograms.

In 10 cases, mitral regurgitation of varying degree was demonstrated. The amount of regurgitation has been estimated radiographically on the basis of the relative degree of opacification in the region of the left atrium. In films of good quality the slightest increase in opacification of the left atrial chamber is considered significant.

The relative size of the left atrial chamber is important in assessing the significance of its opacification by this method. Thus, slight opacification of a large left atrium may indicate just as severe mitral regurgitation as a more marked opacification of a smaller chamber. The method is not quantitatively accurate, but with experience in interpretation one should be able to quantitate the degree of regurgitation roughly as 0, 1, 2, 3, or 4 plus. This is probably adequate for most clinical purposes.

Some estimate of the size of the left ventricle
may also be possible and may be of assistance in diagnosis. Knowledge of the exact time in the cardiac cycle represented on the radiographs, i.e., systole or diastole, would be of value in this regard. Coupling of the x-ray exposures with the electrocardiograph has not been done in this series of cases, however. Other refinements of the method are possible, but the advantage of simplicity is also self-evident.

Figure 6 is a cardioangiogram interpreted as showing 1-plus mitral regurgitation. Definite but minimal opacification is seen in a relatively small left atrium (compare fig. 6A and B). At operation after digital atrial exploration, the surgeon estimated mitral regurgitation as 1 plus.

In a 47-year-old white woman with far-advanced rheumatic heart disease, functional class IV, the cardioangiogram (fig. 7) was interpreted as showing 3-plus mitral regurgitation. At autopsy, 8 months later, a fixed 2 by 1 cm. opening of the mitral valve (fig. 8) was found. The valve edges were markedly thickened and sclerotic, with some calcification.

**Fig. 8.** Photograph of mitral valve (from atrial side) of F. W. Patient died of her disease 8 months after the radiograph demonstrated in figure 7 was obtained. The open fixed mitral orifice measured 2 by 1 cm.

**Fig. 9.** Cardioangiogram of P. F. Four-plus mitral regurgitation with aneurysmal dilatation of the left atrial appendage and without appreciable enlargement of the atrium proper (30 ml. of 90 per cent Hypaque injected in this case).
anteriorly. The chordae tendineae were thickened and shortened. This deformed mitral valve permitted marked regurgitation during life. The left atrium was huge; there were also hypertrophy and dilatation of the left ventricle, moderate aortic stenosis, and hypertrophy and dilatation of the right ventricle and right atrium with functional tricuspid insufficiency.

In another patient with a clinical diagnosis of mitral regurgitation, the routine radiographic studies of the chest, including a lateral with a barium swallow, failed to reveal any enlargement of the left atrium. Cardioangiography (fig. 9) revealed marked mitral regurgitation with an aneurysmal dilatation of the left atrial appendage without significant enlargement of the atrium proper.

Of the 10 cases showing some degree of mitral regurgitation by cardioangiography, then, the valves were explored surgically in 3, and a fourth patient came to autopsy. The interpretation of the cardioangiograms, as to the approximate degree of mitral regurgitation, was found to correlate correctly with the anatomic findings in all 4 cases.

**Discussion**

Cardioangiography is a procedure that can be accomplished simply and with relative safety. Thirty-one ventricular punctures have been performed in 30 patients with no mortality. Ponsdomenech and Nunez reported 56 ventricular punctures without mortality. In the second case of the authors' present series there was a significant morbidity. This case, reported previously, developed ventricular arrest following the injection of contrast medium almost directly into the ostium of the left coronary artery as a result of malposition of the needle tip. Thoracotomy and cardiac massage were required and the patient recovered. He died several months later, however, from a ruptured aneurysm of the thoracic aorta. Autopsy revealed no evidence of the previous cardiac puncture.

The competence or relative degree of incompetence of the mitral valve can be readily assessed by cardioangiography. No other method presently available appears to be as accurate in evaluating this important function of the mitral valve.

Anatomic evidence is available for comparison in 6 of the 20 cases studied in this series. In 5 of these 6 cases there is essential agreement relative to the competence of the mitral valve between the cardioangiographic findings and the subsequent anatomic findings at operation or autopsy. Obviously a much larger series of cases is needed before any final conclusions can be drawn.

**Summary**

Percutaneous puncture of the left ventricle with the injection of contrast medium has been utilized in dogs to depict radiographically the state of competence of the mitral valve. The competent valve before injury and the incompetent valve after surgical laceration of the mitral leaflet has been demonstrated.

Thirty-one ventricular punctures in 30 patients have been carried out without mortality. Twenty of these patients have been studied relative to the state of competence of the mitral valve. The cardioangiograms in 10 patients were interpreted as showing a competent mitral valve and in 10 patients as showing varying degrees of regurgitation.

The correlation between the cardioangiographic findings and subsequent anatomic findings at operation or autopsy has been stressed. It is believed that this method holds promise for determining the presence or absence of mitral regurgitation, and its approximate degree when present.

**Addendum**

Since submitting this paper for publication, 2 additional patients have had cardioangiograms and have subsequently come to operation. The findings at cardioangiography of a competent mitral valve in 1 and a very minimal degree of mitral regurgitation in the other were in precise agreement with the operative findings.

**Summario in Interlingua**

Punción percutanea del ventriculo sinistre con injectione de substantia de contrasto ha essite usate in canes pro establish radiographicamente le stato de competentia del valvula mitral. Esseva demonstrate le valvula in stato
competente ante su vulneration e in stato incompetente post laceration chirurgic del folietto mitral.

Trenta-un punctiones ventricular in 30 patientes ha esiste executate sin mortalitate. Vinti del patientes eseva studiata in re le stato de competentia de lor valvulas mitral. In 10 patientes le cardioangiogrammas eseva interpretata como reflectente competentia del valvula mitral; in le altere 10, illos pareva indicar varie grados de regurgitation.

Es sublineate le correlation inter le constatazioni cardioangiographic e le subsequente constatazioni anatomic al operation o al necropsia. Nos opinia que iste methodo es promittentemente como adjunta in le determination del presentia o absentia de regurgitation mitral e del grado approximative que illo ha attingite.

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