Cineangiocardiographic Assessment of Mitral and Aortic Regurgitation

MINORU HASHIMOTO

This study was performed to determine the validity of pre-operative assessment of mitral and aortic regurgitation by cineangiocardiography. The severity of both regurgitation was evaluated from several viewpoints and the results were compared each other. There was a general agreement between them and some indices suggested the regurgitant flow pattern. Cineangiographic assessment showed a good coincidence with operative findings and the indication for surgery was also discussed.

THE PRECISE knowledge about pathological anatomy and function of the valve lesion is indispensable especially when surgical therapy is proposed but the operative method is not yet decided. Some examination techniques such as right and left heart catheterization and dye dilution curve has been used for this purpose in combination with careful interpretation of electrocardiography, vectorcardiography, phonocardiography and ordinary chest X-ray films. These conventional methods are, however, often less contributory when stenosis and regurgitation coexist or in cases with combined valvular lesions. For example, patients with clinically apical systolic and faint or absent diastolic murmur often show no regurgitation and in those with accompanying mitral stenosis, it is sometimes observed that the stenotic valve area calculated from hemodynamic data is underestimated than the true size\(^1\). To the surgeon who needs not only hemodynamic but also pathoanatomical findings for the sake of proper choice of the operative method, it is of the most importance to prospect directly what happened in cardiac valves and to assess the severity.

Since CHAVEZ\(^2\) performed intracardiac injection of the contrast material in 1946, angiocardiography has supplied a new field the diagnosis of various cardiac diseases because it can provide objective and accurate findings which the other method gives indirectly. When mitral stenosis is pure or accompanying regurgitation is slight, commissurotomy can be easily performed with excellent result. On the contrary when the associated regurgitation is above the mild degree, it is not always clear to decide which is dominant and whether total valve replacement should be advocated without angiocardiographic examination. This is especially true in subjects with bivalvular disease. In this condition, which valve is playing a more responsible role can be easily solved by this method and operative procedure to each valve is to be selected without difficulty.

Today, there is yet a dispute regarding to merits and defects of angiocardiography using a rapid film exchanger and cineangiocardiography\(^3\). The former can yield sharp contrasted and excellently dissolved films which are fitted for the finer observation on details and are applicable to the quantitative analysis of the cardiac performance through the calculation of cardiac work in combination with dye dilution curve or cardiac catheterization. On the other hand, the latter is beneficial to get information on moving structures of the heart in situ. So, cineangiography is often preferable to rapid serial filming in the valvular disease because of being able to get continuous monitoring and furthermore, the equipments being now in a great

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progress\textsuperscript{4,8}.

The purpose of this paper is to describe the cineangiocardio- graphic findings of mitral and aortic regurgitation and to classify their severity from the several view points in order to compare them each other with the aid of anatomical and other examination findings.

\textbf{Materials and Methods}

Thirty-five mitral and thirty-three aortic cineangiograms were included in this study. They consisted of nineteen mitral regurgitation, seventeen aortic regurgitation and sixteen combined mitral and aortic regurgitation (Table I, II and III). Many of mitral regurgitation were associated with various degrees of stenosis, therefore, the mitral valvular disease dispersed from dominant stenosis with slight regurgitation to pure massive regurgitation. There were thirty-two males and twenty females whose ages ranged from ten to forty with the average of twenty-three and twenty-six respectively.

After slight premedication with meperidine and atropine sulphate, a \textit{Kifa polyethylene catheter} with a tapered end and several side holes was introduced percutaneously into the right femoral artery by \textit{Sel-dinger technique}\textsuperscript{6}. When the introduction was not successful, the right femoral artery was preparated by small skin incision and the same procedure was repeated. The catheter was passed retrogradely into the left ventricle across the aortic valve, the tip was positioned in the middle of the ventricle so as to move freely for the protection of arrhythmia and extravasation into the cardiac wall. The contrast material used was 80\% \textit{Angio-Conray} in the most cases and in a few, 76\% \textit{Urographin} was used if the former was not available. One milliliter per kilogram body weight of the contrast material for one injection was satisfactory without any side effect. The injection pressure was six to ten kilograms per square centimeter with the use of a \textit{Gidlund} injector.

After the first cineangiogram was taken in the right anterior oblique position at 45\textdegree, the catheter was withdrawn into the aortic root, the tip of which just above the aortic valve, then the second injection was done in the left anterior oblique position at 60\textdegree. The incidence of success and complications was already discussed by others\textsuperscript{7,8}. The X-ray kit used in this study was 9 inches Siemens image intensifier which was fitted with a built-in television camera and a 16 mm Arriflex cinecamera. The cine speed was 48 frames per second. Fluoroscopy was being kept through the television camera during cine exposure as well as the insertion of the catheter, so that it was possible to watch the process simultaneously. Moreover, a videotape set was attached to the monitoring television system by which all findings were recorded in duplicate, a cinefilm and a videotape, so, the results

\begin{table}[ht]
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\begin{tabular}{|c|c|c|c|c|c|c|}
\hline
\textbf{No. of Cases} & \textbf{Age} & \textbf{Diagnosis} & \textbf{Rhythm} & \textbf{\% on Val. Pl.} & \textbf{Shape of Reflux} & \textbf{N. C.} & \textbf{Opaqica of Aorta} \\
\hline
1 & 25$^{F}$ & MS\textsubscript{I} & SR & 55 & 2 & 5 \\
2 & 30$^{M}$ & MS\textsubscript{I} & AF & 18 & 1 & 3 \\
3 & 39$^{F}$ & MI & AF & 40 & 2 & 6 \\
4 & 33$^{F}$ & MS\textsubscript{I} & AF & 10 & 1 & 2 \\
5 & 15$^{M}$ & MI & SR & 100 & 4 & 12 \\
6 & 17$^{M}$ & MI & SR & 15 & 1 & 2 \\
7 & 16$^{M}$ & MI & AF & 90 & 3 & 10 \\
8 & 23$^{M}$ & MS\textsubscript{I} & AF & 85 & 3 & 8 \\
9 & 17$^{M}$ & MS\textsubscript{I} & SR & 45 & 2 & 7 \\
10 & 15$^{M}$ & MI & AF & 100 & 4 & 10 \\
11 & 31$^{F}$ & MS\textsubscript{I} & SR & 10 & 1 & 2 \\
12 & 19$^{M}$ & MI & SR & 80 & 4 & 10 \\
13 & 35$^{F}$ & MSI & AF & 50 & 2 & 5 \\
14 & 24$^{M}$ & MS\textsubscript{I} & SR & 70 & 3 & 11 \\
15 & 31$^{F}$ & MS\textsubscript{I} & SR & 25 & 1 & 4 \\
16 & 27$^{F}$ & MI & AF & 90 & 4 & 12 \\
17 & 10$^{M}$ & MI & SR & 90 & 3 & 8 \\
18 & 40$^{M}$ & MSI & SR & 65 & 2 & 3 \\
19 & 18$^{M}$ & MI & AF & 95 & 4 & 10 \\
\hline
\end{tabular}
\caption{Results of Patients}
\end{table}

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were evaluated repeatedly immediately after the procedure.

Cinefilms obtained were observed continuously and frame by frame with a Kodak projector and a filmeditor. Sequences presented in this study were reproduced by a method described by RAIDER.9 There was no serious complication experienced in this series.10

**Table II** Results of Patients with Aortic Regurgitation.

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RESULTS

Thirty-five mitral and thirty-three aortic cineangiograms were used for assessment of mitral and aortic regurgitation respectively. After several attempts, we decided the following parameters worth contributory to the classification of the severity of the both regurgitation.

Percent of Regurgitant Portion of Valve Plane

In the right anterior oblique position, the mitral valve is depicted as a profile image and the line of approximation is seen perpendicular to the X-ray beam. In systole, therefore, the reflux passes across the line into the left atrium. In the left anterior oblique position, the aortic valve plane lies slightly downwards inclined in the left, the right coronary cusp being identified left and lower, the left coronary cusp right and higher and the noncoronary cusp most inferiorly between them. Thus, the width of the reflux at the valve plane was presented as per cent on the length of corresponding valve plane.

As shown in Fig. 1 and 2, the value ranged from 10 to 100 per cent in mitral regurgitation and from 25 to 90 per cent in aortic regurgitation owing to the difference of the severity of each patients. In these with mitral regurgitation, all who presented less than 30 per cent belonged to the patients with central regurgitation and dominant stenosis. There were ten cases of such a group. Between 30 and 60 per cent were there five and nine cases were classified as 60 through 80 per cent. The other eleven cases belonged to a group of more than 80 per cent. In aortic regurgitation, seven cases presented less than 30 per cent and ten cases positioned between 30 and 60 per cent. The

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Fig. 1. Correlation between grade of mitral regurgitation and per cent of regurgitant portion on valve plane.

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CINEANGIOCARDIOGRAPHIC ASSESSMENT OF MITRAL AND AORTIC REGURGITATION WITH COMBINED VALVULAR LESIONS

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Fig. 2. Correlation between grade of aortic regurgitation and per cent of regurgitant portion on aortic valve plane.

range from 60 to 80 per cent was occupied by eleven patients and five patients presented more than 80 per cent.

Shape of the Reflux

From the point of view of the shape of the reflux, the severity of both regurgitation was classified into four grades by the following criteria which was used to be applied commonly.

Grade 1. The reflux was assessed as a slight jet; a small amount of the contrast material regurgitated into the left atrium or ventricle during each systole or diastole respectively (Fig. 3 and 4).

Grade 2. The shape of the reflux was not a jet but like a fan in this grade; the left atrium or ventricle was not yet entirely opacified by a single systole or diastole (Fig. 5 and 6).

Grade 3. With the reflux becoming larger, the shape was not clearly identified but the contrast material spread out with wider angle (Fig. 7 and 8).

Grade 4. The contrast material regurgitated massively into the left atrium or ventricle which became opacified immediately and completely at the end of a single systole or diastole following injection. Thus, the shape of the reflux was not differentiated (Fig. 9 and 10).

According to this criteria, thirty-five patients with mitral regurgitation were classified into ten of grade 1 (29%), eight of grade 2 (22%), seven of grade 3 (20%) and ten of grade 4 (29%). Of thirty-three cineangitograms, on the other hand, there were eight and nine cases of grade 1 and 2 respectively. Each represented 25 per cent and 27 per cent in order. Grade 3 group of patients were eleven and five cases were evaluated as severe as grade 4. These two grades represented 33 per cent and 15 per cent respectively.

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When compared to the percent of the regurgitant portion on valve plane, a positive correlation was found both in mitral and aortic regurgitation. All with grade 1 mitral regurgitation showed the percent of less than 25 per cent, whereas in grade 4 patients, seven out of ten cases were calculated to be more than 90 per cent with the average of 92 per cent. Grade 3 group of patients ranged from 60 per cent to 90 per cent, five out of seven cases were between 80 per cent and 90 per cent. Grade 2 patients, though exhibited a wider distribution, ranged from 40 per cent to 80 per cent but all except two were in range of 40 per cent to 65 per cent with the average of 57 per cent.

Of aortic regurgitation, grade 1 group ranged from 20 per cent to 35 per cent with the average of 28 per cent. In grade 2, seven out of nine cases took position between 25 per cent and 58 per cent, the average being 45 per cent. In grade 3, all but one were between 58 per cent and 82 per cent (average 69 per cent) and 78 per cent was the average value in grade 4 group of patients.

Number of the Ventricular Contractions Necessary to Wash Out of the Contrast Material from the Left Atrium or Ventricle

Fig. 3. Mitral regurgitation, grade 1. Right anterior oblique position and left ventricular injection.

Fig. 4. Aortic regurgitation, grade 1. Left anterior oblique position and aortic injection.

Fig. 5. Mitral regurgitation, grade 2.

Fig. 6. Aortic regurgitation, grade 2.

Number of the ventricular contractions during the period between complete opacification of the left atrium or ventricle and complete wash out of the contrast material from corresponding chamber was counted as a parameter to estimate the severity of regurgitation. In patients of slight degree in whom the regurgitated chamber would not fully opacified, the period between the first and the last jet reflux was substituted instead of the definition above. Furthermore, various kinds of arrhythmic beats such as premature beat, transitory brady- and tachycardia and so on were seen in many patients at injection. But some of the abnormal beats were taken into account if these had proved to have the sufficient and effective stroke volume.

As shown in Fig. 11, grade 1 group of the patients with mitral regurgitation demonstrated 2 to 4 contractions and grade 2 group showed 5 to 8 with the average of 5.9. Grade 3 group were between 7 and 11, the average value being 8.7. In grade 4 group, all presented more than 10 contractions (average 11). Correlation with the percent of the regurgitant portion on valve plane was shown in Fig. 12 in which it was demonstrated that in patients with less than 80 per cent regurgitant portion.
and less than 7 contractions, the relationship was almost proportional but if exceeded to more than these values, the relationship became tangential as each increased. As for aortic regurgitation, nearly the same tendency was likely to be seen in spite of a few deviations. Eight out of thirty-three patients exhibited contractions less than 3 and all but two belonged to grade 1 group. On the other hand, four out of five patients who demonstrated more than 11 contractions were classified as grade 4 group. In grade 3 group, the number varied from 7 to 11, the average value was 8.5 and the last nine patients judged as grade 2 revealed 3 through 7 contrac-

Fig. 11. Correlation between mitral grade and number of ventricular contractions (N.C.).

Fig. 12. Correlation between per cent value of regurgitant portion on mitral valve plane and number of ventricular contractions. Note the rapid increase of N. C. above than around 80%.

Fig. 13. Correlation between aortic grade and number of ventricular contractions.

Fig. 14. Correlation between per cent value on aortic valve plane and number of ventricular contractions.

tions (Fig. 13). Correlation of this number with the percent of the regurgitant portion on valve plane revealed that there was essentially the same relationship as in mitral regurgitation (Fig. 14). If an approximate curve had been drawn, it seemed to be more perpendicular than that of the mitral valve, the cause of which was thought to result in that the mitral reflux regurgitated into the left atrium across the nearly full length of the valve plane in moderate to severe patients, whereas in aortic regurgitation of the same severity, the reflux passed through more narrow slit of the incompetent valve.

The difference of the average value of the percent of the regurgitant portion in grade 3 and 4 groups of both regurgitation also seemed to provide a coincidence with the former explanation.

Length of the Opacified Aorta

The length of the opacified aorta was classified into four degrees by the following criteria. The evaluation was made just at the time when the contrast material had completely opacified the left atrium or ventricle. In slight regurgitation in which the reflux had not fully spread out, the evaluation was made when the first reflux was discerned.

+1. Full opacification of the thoracic aorta.
+2. Opacification until the upper half of the descending aorta.
+3. Opacification until the aortic arch.
+4. Opacification until the ascending aorta.
+5. Opacification until just above the aortic valve.

In patients with aortic regurgitation, a relatively close relationship was seen. There was no case of +5 in our series and four out of five patients with grade 4 showed +4. Six out of eight pure aortic regurgitation in grade 3 represented +3. All but one in whom the evaluation did not correspond but the classification due to opacification of the aorta revealed one grade overestimation had combined mitral and aortic lesions. On the contrary, however, was there only a more vague and unclear relationship as to the mitral valve (Fig. 16). In grade 3 patients, a rather good correlation was found but seven out of ten grade 4 patients were evaluated as +4 with the rest being +3. A wider dispersion was observed in grade 2 and 1 in whom an exact assessment of mitral regurgitation would not be made by this way. For example, +3 patients ranged from grade 1 to 4, that is, a distinct differentiation could not be established in this group.

![Fig. 15. Comparison of shape of reflux and degree of aortic opacification. Note overestimation of latter in combined valvular disease (open circle).](image1)

![Fig. 16. Comparison of shape of reflux with degree of aortic opacification in mitral regurgitation.](image2)
Roentgen Cinedensitometry of the Aorta, Left Ventricle and Atrium

The density of the contrast material in the aorta, left ventricle and left atrium before and after injection was measured by a spot densitometer with viewing angle of one degree. The difference of the reading before and after injection at the same spot in each chamber was calculated and the density difference in the left atrium divided by that in the left ventricle was represented as $D_{LA/LV}$. The quotient from the same procedure on the aorta and the left ventricle was $D_{LV/AO}$. Thus each value was anticipated to show the severity of mitral and aortic regurgitation respectively. The deflection was read just at the moment when the left atrium or ventricle was fully opacified by reflux. In subjects showing no full opacification, the measurement was done when the jet reflux was clearly identified.

As shown in Fig. 17, a good relationship was seen between $D_{LV/LA}$ and the severity of mitral regurgitation classified by the shape of the reflux. All grade 1 patients revealed $D_{LV/LA}$ of less than 0.5, grade 2 group of patients ranged from 0.5 to 1.0, that of grade 3 group was between 1.0 and 2.3 and all except one in grade 3 group demonstrated $D_{LV/LV}$ of less than 1.8. In grade 4 group, the minimum value was 1.3 and the maximum was 3.0 with the average of 1.8 which was larger than 1.4, the average of grade 3 group. The reason of the presence of an overlapping between these two groups will be discussed later. Comparison of $D_{LV/LA}$ with the percent value of the regurgitant portion on the mitral valve plane showed a similar curve as presented in Fig. 12 (Fig. 18). Under 80%

![Fig. 18. Correlation between per cent value on mitral valve plane and $D_{LA/LV}$. Note the rapid increase above than around 80%.](image)

![Fig. 19. Correlation between number of ventricular contractions and $D_{LA/LV}$.](image)
per cent and 1.0 of $D_{LA/LV}$, the relationship was almost proportional but it became rather tangential above these values. Comparison with numbers of the ventricular contractions was shown in Fig. 19. Though there were more dispersed distribution of the values in the area of more than 1.0 of $D_{LA/LV}$, it showed the same tendency. This was to be confirmed by Fig. 20 where patients with arrhythmias and the left atrial expansion that could have masqueraded true estimation of the both parameters were eliminated.

Concerning $D_{LV/AO}$ in aortic regurgitation, the same tendency could be observed though there was an overlap between each groups (Fig. 21). Comparison with the percent value indi-

![Fig. 20. Same correlation as in Fig. 19. Cases with arrhythmia and atrial expansion are eliminated.](image)

![Fig. 21. Correlation between aortic grade and DLV/AO.](image)

![Fig. 22. Correlation between per cent value on aortic valve plane and DLV/AO. Solid circle indicates pure aortic regurgitation while open one indicates combined valvular lesions.](image)

![Fig. 23. Correlation between number of ventricular contractions and DLV/AO.](image)
cated that the same kind of curve as in mitral regurgitation could be drawn in pure aortic regurgitation but as to the subjects with combined mitral and aortic lesions, there was no clear relationship between these two parameters. This was also true in comparison with numbers of the contractions (Fig. 23). Thus in combined valvular disease, there was no distinct correlation between optical density and the other parameters.

Regurgitation into the Pulmonary Vein

In those with mitral regurgitation of more than moderate degree, the regurgitant flow has been said often to proceed into the pulmonary vein during ventricular systole. Of thirty-five patients analyzed in this study, there was only one in whom reflux into the pulmonary vein was clearly observed. This patient, a 27 years old female, demonstrated grade 4 regurgitation, the large left atrium, delayed wash out of the contrast material from it and D_{L/AA/LV} of 1.8. The mitral ring was dilated and the leaflets were pliable but not competent along the entire approximation line. The low incidence of the regurgitation into the pulmonary vein in this series may be attributed at least partly, to the left ventricular injection.

Atrial Expansion during Ventricular Systole

Paradoxical left atrial expansion due to the regurgitant flow during ventricular systole was confirmed in seven out of ten grade 4 patients, four out of seven in grade 3 and one out of eight in grade 2. These corresponded to 70 per cent, 57 per cent and 13 per cent respectively. The occurrence of the atrial expansion were likely to have no relation to the presence of atrial fibrillation\(^1\).

Arrhythmia and False Regurgitation

The rapid increase of the left ventricular pressure at the injection of the contrast material or direct stimulus of the catheter tip on the cardiac wall often caused various kinds of arrhythmias such as tachycardia, bradycardia, ventricular premature beats and transitory arrest\(^12\). The over all incidence in this series was 60 per cent, but happened more frequently in grade 3 and 4; 70 per cent, 85 per cent, 62 per cent and 30 per cent in each group respectively. However, the false regurgitation which had been said to be seen in association with arrhythmia and to result in incorrect estimation of regurgitation\(^13,14\) was distinguished clearly only in one patient. But even in this patient, arrhythmias did not continue so long but only once or twice, so that it was not disturbed to estimate his severity. On the contrary, no arrhythmic beat of this kind of origin was found on the estimation of aortic regurgitation.

Assessment of the Accompanying Mitral Stenosis

Various grades of stenosis were associated in many of mitral regurgitation. In order to evaluate these associated stenosis concomitantly, the left ventricular angiograms were carefully watched in regard to the following three items.

1. The thickness of the radiolucent zone

The radiolucent zone between the opacified left atrium and ventricle was thought to represent the profile of the mitral valve, so its thickness was graded on a scale of 0 to 3+ where 0 indicate normal valve thickness and 3+ was used in the thickest zone.

2. The width of mitral valve front which become invisible in diastole

The radiolucent zone can be seen in systole even in the normal mitral valve. But it is expected for mitral stenosis to be identified not only in systole but in diastole due to the commissural fusion and subsequent narrowing of the orifice. The condition in which the zone was visible on 75 per cent or more of the valve front was titled as 3+ and the patients in whom the zone was not visible or less than 25 per cent was visible in diastole were classified to 0.

3. Mobility of the radiolucent zone

The loss of mobility of the stenosis leaflets was assessed by relative movement of the valve ring and radiolucent zone. When the center and the both ends of the radiolucent zone moved coordinately by cardiac beat, the valve was supposed to be not pliable. So, its severity was graded into 0 to 3+ as previously.

As shown in Table I, II and III, the three factors were usually in parallel but sometimes differed a little each other. Comparison with anatomical findings proved at operation of twenty patients was listed in Table V. Retro-
spectivey speaking, the actual presence of stenosis had been identified cineangiographically before operation with no exception, but angiograms had often provided false information which became clear later at operation. Table IV was a summary of correlation between cineangiograms and the operative findings as to whether stenosis was actually present or not. Among three factors mentioned above, visibility of the valve front in diastole proved to have the best diagnostic value with the accuracy of 83 per cent, whereas the thickness of the radiolucent zone proved not to be amenable for the detection of the stenotic mitral valve. The diagnostic value of the relative mobility of the cusps was 66 per cent.

Correlation of the Degree of Mitral Regurgitation with the Left Atrial Pressure Tracings

The left atrial pressure tracings obtained during operation or by transseptal left heart catheterization were submitted to the calculation of \((v - y)/y\) which was adopted as an representative index indicating the severity of mitral regurgitation. Comparison with the per cent value revealed a rapid increase of \((v - y)/y\) in more than 80 per cent, whereas the correlation was almost proportional under 80 per cent (Fig. 24). This result coincided well with the results mentioned before and the explanation of the coincidence will be discussed later.

Arterial Puls Pressure

The magnitude of the arterial puls pressure was plotted against the classification due to the shape of reflux. As shown in Fig. 25, there was no significant difference among four groups. The average values of the puls pressure in slight to severe grade of patients were 47, 72, 71 and

![Fig. 24. Correlation between per cent value of mitral regurgitation and \((v - y)/y\) of left atrial pressure tracings.](image)

![Fig. 25. Correlation between aortic grade and magnitude of arterial pulse pressures.](image)
were listed in Table V and VI together with the operation methods performed. As to the mitral valve, all of grade 1 group had dominant mitral stenosis with trivial regurgitation. The leaflets were stiff and fibrotic and the both commissures were usually fused each other. The regurgitation was seen in center of the orifice mostly and the free margin of the leaflets somewhat shrunk through which the reflux was palpable at operation. In grade 2 group, the reflux increased to an extent in which not only central but one commissural regurgitation were palpated, but stenosis stayed yet dominant or at least, regurgitation did not exceeded stenosis. Among the patients of grade 1 and 2, seven were underwent to blind commissurotomy but the regurgitation remained unrepaired because it was negligible. Other two were indicated to the total replacement with Starr-Edwards ball valve because it was anticipated that commissurotomy would have made regurgitation severe. On the contrary, in grade 4, the valve was incompetent entirely along the line of approximation and the ring was dilated in half of

**Electrocardiogram**

The magnitude of $Rv_3 + Sv_1$ was plotted against the severity of regurgitation individually. Fig. 26 shows the relationship between the severity of mitral regurgitation and $Rv_3 + Sv_1$, in which it was observed that there was no significant difference between each group nevertheless of the combined aortic lesion. Fig. 27 revealed that the more the severity of aortic regurgitation increased, the more the average value of $Rv_3 + Sv_1$ became larger in spite of the presence and the severity of the combined mitral lesions. In grade 4 group, though all subjects had pure aortic regurgitation, the left ventricular hypertrophy was distinguished and all had $Rv_3 + Sv_1$ of more than 7.8 mV which none of the severest mitral regurgitation exhibited. The highest value in pure mitral lesion was 7.0 mV but in pure aortic valve lesion, all but two showed $Rv_3 + Sv_1$ of more than 7.0 mV.

**Anatomical Findings Proved at Operation**

The anatomical findings proved at operation

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Fig. 26. Correlation between mitral grade and $Rv_3 + Sv_1$ of electrocardiograms.

Fig. 27. Correlation between aortic grade and $Rv_3 + Sv_1$ of electrocardiograms.
the patients. Though shortened and retracted, the leaflets were thin and pliable. In some of them, the margin was fibrotic.

The operative findings of the aortic valve were obtained chiefly in grade 3 and 4 groups. It was because operation was not usually intended to the slight regurgitation. In grade 2 group, regurgitation was restricted to the center of the orifice and the valve deformity was not remarkable. In grade 3 group, regurgitation was nearly of central origin and the commissures were fused in three of seven subjects. The leaflets were occasionally stiff and fibrotic and the retraction was seemed to be responsible for regurgitation. In grade 4 group of patients, all but one showed marked regurgitation originating from the loss of the valve substance. The commissures were not fused in all but the cusps were pliable except one in whom calcification deposit was found. In one patient, a 14 years old male, a large perforation on the non-coronary cusp was the cause of regurgitation. Thus, anatomical findings in the mitral disease removed from stenosis to regurgitation as grade increased and the transitional zone was seemed to be between grade 2 and 3. The aortic valve deformity was trivial in grade 1 and 2 and as a rule, the aortic valve replacement should be performed in grade 3 and 4.

**DISCUSSION**

The application of the angiography into the valvular disease was advocated **Ponsdome**-**Nech** in 1951 and thereafter many reports concerning the usefulness and accuracy of this method in diagnosis of mitral and aortic regurgitation have been published. Meanwhile, introduction of image intensifier into cineangiography by **Teves** and **Fedman** in 1955 also made a rapid advance in this field together with improvement of the sensitivity and resolving power of cinefilm. The preoperative assessment of the regurgitation either by serial radiography or cineangiography has usually depended on classification of the severity into several grades and on comparison with the

<table>
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<tr>
<th>Table V</th>
<th>Operative Findings of Mitral Valve and Method of Treatment</th>
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<tr>
<td><strong>No. of Cases</strong></td>
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operative findings. This was adopted by Starobin, Uricchio, Gray, Gilman, Smith and so on. However, it is desired that though the grading method is almost sufficient for practical purpose, quantitative or at least semiquantitative way of estimation should be introduced if possible. The left ventricular volume determination by angiography fulfills the object in part and by which volume and percent of the regurgitant flow can be calculated. Moreover, myocardial function and ventricular work of the diseased heart can be estimated by this, but volume determination has some restrictions such as not only the meticulous calculation but the patient’s position and site of injection. Many of the left atrial and ventricular volume determination have been performed through a catheter in the pulmonary artery or via transseptal route in the antero-posterior position for the complete opacification of the left sided chambers and prevention of arrhythmic beats. However, details of the incompetent valve can not be obtained by this way and the method does not differentiate between the mitral and aortic regurgitation nor does it permit separate determination of the volume of aortic and mitral regurgitant flow in subjects with both lesions. From these reason, the author adopted an intermediate way where the localized findings and semiquantitative relation with the degree of regurgitation can be both obtained.

In the right anterior oblique position, the aortic leaflet of the mitral valve is in front and the mural leaflet behind it. The anterior commissure is up to the right and the posterior commissure down and to the left. Thus, as the full diameter of the mitral annulus represents the full length of the line of approximation, the percent value of the regurgitant part on the diameter of the mitral orifice will be anticipated to correlate closely with the shape of reflux. It should be noted as to the results that grade 1 subjects are clearly separated from the other but the difference between grade 3 and 4 is small and sometimes patients with the same percent value are divided each other. This may reflect the fact that the width of the approximation line is not measurable in one direction and slight increase in the percent value will cause a large volume increase of the reflux. This explanation can be applied to the aortic valve too, but smaller diameter of the aortic orifice and the bulging of the sinus of Valsalva cast some difficulty together with non perpendicular X-ray beam to the line of approximation owing to the tricuspid valve. These peculiar conditions result in underestimation of the apparent

<table>
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<tr>
<th>No. of Cases</th>
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*Table IV Operative Findings of Aortic Valve*
diameter than the true one. The narrow difference between each grade may be attributed to these conditions.

The idea of counting the number of ventricular contractions as an index of the length of emptying time of the left atrium was stated by Björk\textsuperscript{12}. He reported that the length of the emptying time of the left atrium will give a general, though not ideal, indication of the degree of heart disease and the classification by this way is mainly influenced by atrial fibrillation. It is also said that emptying time measured in number of ventricular contraction are not fully exact and the number of the contraction is more reliable to assessing the degree of mitral regurgitation than that measured in seconds. Moreover, there is no correlation with the mobility of the mitral leaflets, calcification in the mitral orifice thickness of the left ventricular wall. Presumably, it might be imagined that in subjects with combined valvular regurgitation, the contrast material injected in the left ventricle stays longer due to aortic regurgitation, so that the number of ventricular contractions concerning the mitral valve might be counted more than actual. But there is no disparity between mitral and combined regurgitation, the reason of which may be attributed to the increased stroke volume that makes the contrast material undiscernable because of the low concentration. The numbers concerning the aortic injection in the combined regurgitation remain also equal to the isolated aortic regurgitation but relationship with $D_{LV/AO}$ shows a different result, which may indicate that $D_{LV/AO}$ is a finer method than number counting. Wider distribution of the values in above moderate patients in Fig. 12 illustrates inevitable integration of arrhythmic beats or increasing accumulation of such factors that may effect on the result.

The classification by aortic opacification in mitral regurgitation was offered by Björk\textsuperscript{12}. The same kind of grading tried in this paper is roughly able to differentiate the severity of each grade group. However, main difficulty in assessing the grade by this method consists in that, in our series, there is no subjects who belonged to $+5$ and that overlapping of the various groups is seen $+2$ and $+3$. From the surgical standpoint, it is the most important to decide whether artificial heart valve should be inserted or heart lung machine should be prepared. In this regard, it is desired that any sort of grading should, at least, be able to differentiate primarily the patients who need the valve replacement from another. This is especially true in the combined valvular disease, as stressed by Cohn\textsuperscript{27}, in whom the valve to be treated by the replacement should be decided preoperatively.

The results obtained from Roentgen cinedensitometry offers an interesting problem. The quantitative investigation by cinedensitometry in vitro and in carotid artery of dogs was studied by Rutishauser\textsuperscript{40} and the some other papers have been issued\textsuperscript{41,42,43}. According to him, the light intensity measured on cineangiographic films projected onto a screen could provide an indicator dilution curve for the flow measurements that proved to be highly coefficient with the actual blood flow. Being thought that the light intensity measured by a photoelectric cell in the left sided heart and aorta before and after injection of the contrast material reflects relative concentration of the contrast material and its quotient reveals the rate of the regurgitant flow, the quotient represented as $D_{LV/AT}$ and $D_{LV/AO}$ was compared with other parameters. In mitral regurgitation, correlation with both percent value and the number of ventricular contractions gives essentially the same result; that is, in the patients showing less than 80 per cent and seven contractions, $D_{LV/AT}$ is also less than 1.0 and within these ranges, the relation of each other is almost proportional, but above these borderlines, $D_{LV/AT}$ increases tangentially as well as other parameter often do. This may reflects the fact that the rapid increase of the regurgitant flow may occur. Fig. 20 illustrates more clearly the result, in which the subjects with both arrhythmias and left atrial expansion were omitted because these were thought to masquerade the correct expression of the light intensity. The reason of why presence of the combined aortic regurgitation does not hinder the result may consist in the time of the measurement which was mentioned previously. At that time, the aortic reflux is not yet promi-

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nent. In aortic regurgitation without combined mitral lesion, the range within which the linearity can be held is likely to be in 0.8 of $D_{LV/AO}$ or less, 50 per cent of the percent value or less and seven contractions or less. Above them, $D_{LA/AO}$ increases rapidly as well as in mitral regurgitation. On the contrary, cases with combined mitral disease do not give a constant result the cause of which may be in the fact that the regurgitated flow in the left ventricle regurgitates again into the left atrium.

There are many reports concerning the left ventricular volume determination on patients with mitral and aortic regurgitation. According to them, patients with valvular regurgitation have large end-systolic and end-diastolic volumes which result in large left ventricular stroke volume. The degree of enlargement of end-diastolic volume is related to the volume of regurgitant flow. Arvidsson stated that either of end-systolic and end-diastolic volume increases at about 50 per cent regurgitation but in less than 50 per cent, there are little increase in both volumes. He mentioned furthermore, that above 50 per cent regurgitation end-diastolic volume increases markedly whereas end-systolic volume increases gradually which results in progressive increase of the total left ventricular ejection volume. As cardiac output stays constant or somewhat decreases in valvular regurgitation, it could be said that the regurgitation volume enlarges progressively above 50 per cent regurgitation. Thus the interrelationship between the regurgitation volume and the percent value of the regurgitant flow provides the similar result to that seen in our measurement of the light intensity and warrants the validity of our results.

As to false regurgitation, Stauffer presented that the false regurgitation depends on the presence of a long period of ventricular diastole such as excessive bradycardia, compensatory pause after premature beat, asystole and sinus arrhythmia. Massih also reported that in compensatory pauses of premature beat, diastolic regurgitation is seen and with the next normal beat, the unexpected findings of systolic regurgitation is frequently observed. In our series, there was only one case of such findings, so that it seems for us that the incidence and the severity of the false regurgitation is relatively low as Björk mentioned. As with the atrial expansion, the sign of paradoxical is not a reliable guide to the severity of the patients as cited by Dinsmore.

The evaluation of mitral stenosis reveals that it is of the highest diagnostic value to measure the extent of the mitral valve plane seen in diastole. The other two indices are reliable when the stenosis is actually present but are not useful for detection of the stenosis. This is partly because partial disappearance of the plane in diastole is easily remarkable and partly because other two indices may be more comparative way of the estimation. Of these two, the mobility of the valve plane is of a little better value than the thickness of the plane. The densitometric quantification suggested by Ross would be a valuable method when the contrast material is injected via pulmonary artery or in the left atrium, but in the left ventricular injection, it could not be utilized. As a whole, the left atrial injection may be the best for the detection and evaluation of mitral stenosis since it provides the thickness and mobility by a positive contrast. The unreliability of observing the stenotic dome protruding into the opacified ventricle and of evaluating the thickness and mobility as well as pulmonary venous reflux by left ventricular injection were stressed by Ross.

Analysis of the left atrial pressure tracings has been performed using several indices. Though, sometimes, the severity of accompanying mitral regurgitation could not be determined accurately under the coexistence of mitral stenosis, correlation between $(x-y)/y$ and the percent of the regurgitant portion on valve plane indicates similar result to that on cineangiography. The inherent defect involved in this index seems to be underestimation of the regurgitation, but at least in our series, coincidence of cineangiography and analysis of the left atrial pressure tracings probably reflects the severity accurately especially when the operative findings are thought of together. On the contrary, the arterial pulse pressure does not correlate with the severity of aortic regurgitation. Cohn, stating the high availability of root cineangiography, stressed also that the
pulse pressures are least contributory as well as the systemic arterial diastolic pressures are.

Electrocardiogram of the patients with mitral regurgitation showed that the left ventricular hypertrophy occurred in only 30 per cent and a normal ventricular complex was present in 50 per cent\textsuperscript{20}. Though the presence of accompanying mitral stenosis might have an effect on ventricular complexes theoretically, there is no difference as \textcolor{red}{URICCHIO}\textsuperscript{20} reported. Thus, the electrocardiogram is of little help either in pure or in combined mitral regurgitation. The relatively reliable coordination of electrocardiogram in aortic regurgitation may be due to the fact that the energy loss in this condition is higher than in mitral regurgitation so that the effect of aortic regurgitation is dominant than the latter.

Our assessment of regurgitation agreed well with the operative findings. \textcolor{red}{URICCHIO}\textsuperscript{20}, in comparing the operative findings with his 4 grades, reported that in 4+ group of patients, all had pure mitral regurgitation and in 1+ group, mitral stenosis was dominant. In 2+ and 3+ group, though there was a mixing of combined lesion, combined lesion was much in 2+ and less in 3+. This is supported by others\textsuperscript{21-23,52}. \textcolor{red}{GRAY} and \textcolor{red}{Rees} stated that the valvotomy should be limited to their grade 1 group. In our opinion, grade 3 and 4 should be advocated to the valve replacement and grade 1 group can be treated by closed commissurotomy. Grade 2 group can be repaired by open commissurotomy or occasionally by the closed method though it is not certain to win a beneficial result. As to the aortic valve, general agreement can be held with \textcolor{red}{COHN}'s assessment\textsuperscript{24}. That is, all of +4 and most of those with 3+ regurgitation will require aortic prosthetic valve. Adding to this, we concluded that 1+ grade patients do not need the valve replacement and a half or a third of those with 2+ regurgitation will require the valve replacement.

**Summary**

The cineangiographic findings of mitral and aortic regurgitation were studied in 19 of those with mitral, 17 of aortic and 16 of combined valvular lesions. The severity was determined from several viewpoints in both regurgitation by left ventricular and aortic injection and the following conclusions were obtained.

1. Per cent of the regurgitant portion on valve plane increased with the grade of severity classified from the shape of reflux. But the degree of the increase was slow in last 2 of 4 grades.

2. Number of the ventricular contractions counted as an index of the length of emptying time from the left sided chambers increased proportionally with the percent value in less than around 70 per cent, while it increased rapidly above that value.

3. Estimation by degree of opacification of the aorta proved not so remarkably reliable.

4. Cine densitometric evaluation of the valvular regurgitation revealed a good reliability. The light intensity enlarged tangentially above around 70 to 80 per cent of the percent value. This agreed well with the result stated in 2. Moreover, it seemed to reflect the fact that the regurgitant volume increased rapidly in those with above moderate degree of regurgitation. This can not be applied to evaluation of aortic valve in combined valvular lesions.

5. Atrial expansion had no relation to the presence of atrial fibrillation. False regurgitation did not disturb the evaluation of regurgitation.

6. Assessment of mitral stenosis was not exact in ventricular injection but the width of the part which became invisible in diastole was of the highest diagnostic value.

7. Cineangiographic assessment agreed well with analysis of the left atrial pressure tracings.

8. Arterial pulse pressure did not show the degree of severity of aortic regurgitation.

9. Electrocardiogram did not correlate with the degree of mitral regurgitation but to some extent, correlated with the degree of aortic regurgitation.

10. Operative findings agreed well with the preoperative cineangiographic assessment.

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REFERENCES


18. Teves, M. C.: Image intensification. Read at the Annual Congress of the British Institute of Radio-


