The Left Ventricular Eccentricity as a Predictor of Postoperative Cardiac Performance in Valvular Heart Diseases

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A clear correlation expressed by the following equation was observed between the preoperative left ventricular end-systolic eccentricity ($\varepsilon_s$) and the percentage change of the left ventricular dimension ($\%D$) in chronic valvular heart diseases: $\%D = 88.37 \varepsilon_s - 48.16$ ($r = 0.66$, $p < 0.001$). Therefore, $\varepsilon_s$ may function as an index for predicting the postoperative cardiac performance independent of the affected valvular locations and the morphology of the lesions.

WHEN is the optimal timing for surgical treatment of valvular heart diseases? This is a question which has been discussed for a long time from various points of view, but is as yet without a clear resolution. However, it is reasonable that the operative procedure be performed at least before irreversible myocardial dysfunction occurs. Various hemodynamic measurements which have been used up to now give no clue to anticipate an occurrence of an irreversible impairment of the myocardial function. The authors have already reported that a decreased left ventricular eccentricity, calculated from a preoperative left ventriculogram, can identify a group of patients who have a high operative risk.

This paper is a preliminary report on the anticipation of the postoperative left ventricular function based on the left ventricular eccentricity which was calculated by a preoperative left ventriculogram.

METHODS

The subjects in this study were 44 patients, who underwent a single valve replacement and had no major associated disorders.

In the aortic valve replacement (AVR) group, some cases were associated with mild or moderate mitral valvular disease, and a few received mitral valve plasty simultaneously. The Lillehei-Kaster tilting disc valve was used as the prosthetic valve.

In the mitral valve replacement (MVR) group, some cases were also associated with mild aortic regurgitation and/or stenosis that needed no surgical managements, and the Björk-Shiley tilting disc valve was used as the prosthetic valve.

The left ventricular function was evaluated echocardiographically about 6 months postoperatively. In all these cases, a preoperative left ventriculogram of sufficient quality for an accurate volume analysis and adequate hemodynamic measurements could be obtained by a cardiac catheterization study.

The calculation methods of the left ventricular...
eccentricity were as follows:

The left ventricular configurations are traced in both end-systolic and end-diastolic phases from the left ventriculogram taken at posteroanterior and lateral projections. The long axis (L) was measured in each projection and a left ventricular area (A) was obtained by a planimeter.

Using Dodge’s formula \( D = \frac{4A}{\pi L} \) in each phase can be calculated as follows:

\[ D = \frac{4A}{\pi L} \]

The left ventricular eccentricity (\( \varepsilon \)) can be given by Vokonas’ \( \varepsilon = \sqrt{L^2 - D^2} \) using L and D:

\[ \varepsilon = \sqrt{L^2 - D^2} \]

\( \varepsilon \) and \( \varepsilon_D \) represent the eccentricities in the end-systolic and end-diastolic phases respectively.

Two examples of the above calculation methods are presented below:

Case 1 (Fig. 1, a and b)

This was a 46-year-old male with anginal pain. His left ventricular long axis was measured as 12.50 cm at the posteroanterior projection in the end-systolic phase. This value was longer than that at the lateral view. The picture gave 52.10 cm\(^2\) as the left ventricular area (A). Then, Ds was calculated as 5.31 cm, i.e.,

\[ Ds = \frac{4 \times 52.10}{\pi \times 12.50} = 5.31 \]

The left ventricular long axis in the end-diastolic phase was also longer at the posteroanterior projection than at the lateral view, and a L of 15.00 cm and an A of 83.19 cm\(^2\) were obtained.

These values gave a Dd of 7.06 cm from

\[ Dd = \frac{4 \times 83.19}{\pi \times 15.00} \]

\( \varepsilon_d \) was calculated as 0.906 from

\[ \varepsilon_d = \sqrt{12.50^2 - 5.30^2} \]

and \( \varepsilon_d \) as 0.882 from

\[ \varepsilon_d = \sqrt{15.00^2 - 7.06^2} \]

\[ \frac{15.00}{12.50} \]

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these values were in the normal range.

Case 2 (Fig. 2, a and b)

This was a 44-year-old male with severe mitral stenosis and tricuspid regurgitation, showing a cardiac index below 2.0 L/min/m² by the thermodilution method. In this case, the left ventricular long axis was 8.43 cm and the area was 50.13 cm² in the end-systolic phase, and 14.50 cm and 79.38 cm² in the end-diastolic phase, respectively. &s and &D were calculated as 0.439 and 0.877 respectively. These values shifted from the normal range, particularly in the end-systolic phase.

Besides the left ventricular eccentricity, the left ventricular weight index, wall thickness, end-systolic and end-diastolic volume indexes, stroke volume index and usual hemodynamic measurements were also used as parameters for the evaluation of the preoperative state.

Echocardiographic evaluation was utilized for assessing the postoperative cardiac performance. Percentage change of the left ventricular dimension (%ΔD, Fig. 3) and the mean velocity of circumferential fiber shortening (mean Vcf) were the parameters concerned. %ΔD and mean Vcf can be expressed by the following equations:

$$%\Delta D = \frac{Dd - Ds}{Dd}$$

$$\text{mean } Vcf = \frac{2\pi (Dd - Ds)}{ET \cdot 2\pi Dd} = \frac{Dd - Ds}{ET \cdot Dd}$$

RESULTS

The objective cases were divided into 2 groups, the AVR and the MVR, and the mean &s and &D were calculated in each group.

In the AVR group, &s and &D were 0.883 ± 0.049 and 0.802 ± 0.039, and in the MVR group they were 0.876 ± 0.051 and 0.820 ± 0.038 respectively. No significant differences were observed between the 2 groups. Thus, the eccentricity should be considered as an index independent of the sort of the valve involved.

The Relationship between Preoperative &s and Postoperative %ΔD: Correlations of %ΔD = 79.58 &s - 41.00 (r = 0.63, p < 0.001) and %ΔD = 96.14 &s - 54.46 (r = 0.69, p < 0.001) were obtained for the AVR and the MVR groups respectively. In the total cases combining the two groups, a correlation of %ΔD = 88.37 &s –
Fig. 5. The relationship between the preoperative $\%\Delta D$ and the postoperative $\%\Delta D$.

Fig. 6. The relationship between the preoperative $\sigma s$ and the postoperative mean Vcf.

Fig. 7. The relationship between the preoperative $\sigma D$ and the postoperative mean Vcf.

48.16 ($r = 0.66$, $p < 0.001$) was observed (Fig. 4). The relationship between Preoperative $\sigma D$ and Postoperative $\%\Delta D$: Correlations of $\%\Delta D = 95.69 \& D - 43.74$ ($r = 0.67$, $p < 0.001$) for the AVR group, $\%\Delta D = 121.39 \& D - 70.24$ ($r = 0.60$, $p < 0.01$) for the MVR group and $\%\Delta D = 96.53 \& D - 47.99$ ($r = 0.52$, $p < 0.01$) for total cases were found (Fig. 5).

The relationship between Preoperative $\sigma s$ and Postoperative Mean Vcf: In combining the 2 groups, a correlation given by mean Vcf = 1.64$\sigma s^{3.74}$ ($r = 0.60$, $p < 0.001$) was observed (Fig. 6).

The relationship between Preoperative $\sigma D$ and Postoperative Mean Vcf: In the total cases combining the two groups, a correlation of the mean Vcf = 2.10 $\& D^{3.25}$ ($r = 0.52$, $p < 0.01$) was found (Fig. 7).

**DISCUSSION**

Though the severity of the valvular heart diseases is usually expressed by a pressure gradient across the valve in stenotic lesions and by a regurgitant volume in incompetent lesions, surgical risk for such valvular diseases cannot be determined by these severities alone. In other

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words, hemodynamic severity is not a definite condition which recommends non-surgical management of these valvular heart diseases.

Some cases were lost due to a cardiogenic cause in the early and late postoperative stages, and in some cases, though the valvular functions could be improved after the operation, their life activities as well as overall cardiac performance could not be improved as expected.

The final aim of the surgical treatment for valvular heart diseases is indeed not only the correction of valvular function but also the improvement of the overall cardiac performance. Therefore, surgical procedures should be applied to those cases expected to have improved cardiac performance postoperatively. The precise assessment of this critical point is extremely important for the cardiologist as well as cardiac surgeons. We believe that whether or not the cardiac performance can be improved after surgery depends on the presence or absence of irreversible myocardial dysfunction.

On the other hand, some parameters, which may predict the degree of improvement in the postoperative life activities, have been proposed in each valvular disease as we have reported previously. They are the left ventricular weight index and the wall thickness in aortic stenosis, the left ventricular end-systolic volume index and the end-diastolic pressure in aortic regurgitation, the mean pulmonary arterial pressure and the stroke volume index in mitral stenosis and the left ventricular end-systolic volume index and ejection fraction in mitral regurgitation.

These parameters are thought to be only the reflection of hemodynamics in each valvular disease, and do not always indicate the presence of an irreversible myocardial dysfunction. If these parameters reflect a myocardial dysfunction, the parameters must be independent of the valvular locations involved and the morphology of the lesions.

How does myocardial dysfunction, i.e., diminished contractile performance of the myocardial fiber affect the cardiac functions as a whole? The authors have studied using the following hypotheses:

First, from the functional point of view, myocardial dysfunction appears in accordance with decreases of the stroke volume index and the ejection fraction.

Second, the above functional changes are phenomena secondary to changes in the left ventricular end-systolic and/or end-diastolic volume index.

Third, the left ventricular end-systolic and end-diastolic configurations deviate from the norm as a result of the compensating mechanism for the decreased myocardial contractility and for the volume changes.

As described above, the left ventricular end-systolic eccentricity (%) was shown to correlate well with ΔAΔ and fairly well with the mean Vcf. These correlations were observed in all cases irrespective of the sort of valve involved.

These results suggest that %ΔA derived from preoperative left ventriculogram can be an index for predicting the cardiac performance after valve replacement.

Strictly speaking, the present results must be regarded as only a suggestion of an availability of %ΔA in future, since we cannot still explain the following discrepancies:

If %ΔA is the index for predicting postoperative cardiac performance, ΔAΔ would be useful as well. However, as mentioned earlier, preoperative ΔAΔ does not always reflect the postoperative cardiac performance as preoperative %ΔA does. Next, since myocardial contractile performance correlates well with the end-systolic fiber length in experimental studies, the preoperative left ventricular end-systolic volume should reflect the postoperative cardiac performance in clinical cases.

In our studies, preoperative %ΔA has been shown to correlate with the left ventricular end-systolic volume, supporting the usefulness of %ΔA. However, such a good correlation was not found between the preoperative end-systolic volume and the postoperative cardiac performance as was observed between the preoperative %ΔA and the postoperative cardiac performance. This discrepancy may disappear if the number of cases under study is increased.

Since a reliable index for predicting the postoperative cardiac performance must be derived from the morphological changes of the myocardium, more precise indexes must be found by studying the myocardial structure itself. Such index(es) will enable us to accurately assess the optimal timing for surgical management of valvular heart diseases.

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