The Changes in Pattern of Myocardial Shortening by Reduction of Regional Coronary Blood Flow

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SUMMARY

The relationship between the grade of a decrease in the regional coronary blood flow and the movement of ventricular myocardium of that region was investigated in open chest dog. Blood flow in left anterior descending artery (FLAD) was reduced by stepwise constriction of LAD with ligature. Ventricular segment length was measured in a circumferential plane on the endocardial surface by ultrasonic dimension system. For the elimination of the noise caused by ultrasonic dimension system, the synchronizer was inserted between sample clock of the dimension system and the trigger circuit of the electromagnetic flowmeter.

A 20% reduction of FLAD affected the pattern of ischemic myocardial shortening very little. Discontinuance of shortening to the end of systole was occurred by a 20 to 60% reduction in FLAD. Early and/or late systolic bulging was induced by a 60% reduction of FLAD. Systolic bulging with early diastolic shortening was seen in the cases with a 60 to 80% reduction in FLAD. Frank systolic bulging which was always seen by complete occlusion of LAD was produced by a 60 to 90% reduction of FLAD in few cases.

Additional Indexing Words:

Ultrasonic dimension system Segment length Systolic bulge

SINCE the classical work of Tennant and Wiggers,¹⁾ the changes in pattern of regional myocardial segment shortening during acute coronary occlusion have been described by several investigators.²⁾⁻⁸⁾ However, the precise observations of those changes during a decrease in coronary blood flow were incomplete because of the inappropriate apparatus for continuous measurement of the myocardial segment length. At the present, ultrasonic crystals are considered to be the best equipment as a dimension gauge,⁹⁾⁻¹³⁾ but some

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technical expedients were necessary to apply this technique together with the electromagnetic flowmeter. The purpose of this study is to show the relations between a degree of coronary blood flow reduction and the changes in pattern of myocardial segment shortening in the ischemic area.

METHODS

Fourteen mongrel dogs (15–27 Kg) were anesthetized with sodium pentobarbital (25 mg/Kg i.v.). A left thoracotomy was performed via fifth intercostal space under the artificial ventilation by Harvard pump through an endotracheal tube. After the pericardiotomy, the left anterior descending artery (LAD) was dissected about 1 to 3 cm below the bifurcation and the probe of an electromagnetic flowmeter (EMF, Nihon Koden Kogyo) was applied. Another probe of EMF was placed around the root of ascending aorta. Aortic pressure was measured through a catheter advanced from femoral artery and left ventricular pressure was measured through a short side hole cannula inserted into the apex. A pair of small ultrasonic crystals were implanted into the endocardial surface of the left ventricle perfused by LAD in a circumferential plane. The distance between the crystals was 7 to 15 mm. Continuous measurement of the myocardial segment length was performed by Ultrasonic Dimension System (Schuessler). These hemodynamic measurements were recorded simultaneously on an ink oscillograph.

In this measurement system, the intermodulation which was caused by the interference between electromagnetic flowmeter and ultrasonic dimension system made the recording of blood flow impossible. To avoid this problem, the synchronizer was inserted between the sampling clock of the dimension system and the trigger circuit of the EMF (Fig. 1).

A reduction of blood flow in LAD (FLAD) was produced by inserting the wedge into the loop of the ligature tied loosely around LAD distal to EMF probe (Fig. 2). With this technique, precise adjustment of FLAD was impossible and continuous hemodynamic changes produced by stepwise reduction of FLAD could not be recorded in each case.

After recording hemodynamic data of the control state, hemodynamic changes were observed during LAD obstruction of 15 sec and after release of it. When all

Fig. 1. To avoid intermodulation the synchronizer was inserted between the sampling clock of the dimension system and the trigger circuit of the electromagnetic flowmeter.

Fig. 2. Schematic diagram of preparation. AoPr=aortic pressure; AoF=aortic blood flow; CBF=coronary blood flow; LAD=left anterior descending artery; LVPr=left ventricular pressure; LCX=left circumflex artery; PA=pulmonary artery; GCV=great cardiac vein.

hemodynamic data returned to the control state, FLAD was reduced to as many stages as possible. To get steady state, stable FLAD was kept for 5 min.

RESULTS

Course of the formation of the systolic bulge in the left ventricle by LAD occlusion:

During 5 min of LAD occlusion in 5 cases, the course of systolic bulge formation was observed. Four characteristic patterns were found in each experiment (Fig. 3). Discontinuance of shortening of the myocardial segment to the end of systole or late systolic elongation occurred as the first change (Stage 1). Following this stage, early and late systolic bulging accompanied with or without early diastolic shortening was appeared (Stage 2). The stage of systolic bulging with early diastolic shortening (Stage 3) was likely to be followed by the stage of more prominent pansystolic bulge and disappearance of early diastolic shortening (Stage 4). Although progressive elongation of the myocardial segment at the end of diastole made the determination of that pattern sometimes difficult, the shift from one stage to another was consistently appreciated but continuation of each stage was variable.

Fig. 3. Four characteristic patterns of segment length in the ischemic area after the ligation of the left anterior descending artery.

Fig. 4. The representative recordings of hemodynamics following a 20% reduction of left anterior descending coronary blood flow. Ao=aorta; LV= left ventricle; CO=coronary.

The course of the disappearance of bulge during reperfusion was roughly in a retrograde fashion of the course of bulge formation, but close observation disclosed many exceptional changes in pattern.

Relation between a decrease in coronary blood flow and the changes in pattern of myocardial segment shortening:

Twenty-one tracings in 6 stages of reduction in FLAD, namely 20%, 40%, 60%, 80%, 90%, and 100% reduction, were obtained. Three of cases with a 20% reduction did not reveal any change in pattern of myocardial segment shortening in the ischemic area (Fig. 4). One case with a 20% reduction showed the stage 1 pattern. A 40% reduction of FLAD which was produced only in 1 case, resulted in the stage 1 pattern of ischemic myocardial segment shortening (Fig. 5). The changes in pattern of myocardial segment shortening induced by a 60% reduction of FLAD were extremely variable. Fig. 6 showed an example of early systolic hypokinesia and endsystolic small

Fig. 5. Stage 1 pattern in a case with a 40% reduction in FLAD.
FLAD=blood flow in LAD.

Fig. 6. Stage 2 pattern in a case with a 60% reduction in FLAD.

bulge (Stage 2). Of 7 cases with a 60% reduction, the stage 1 pattern was introduced in 2, the stage 2 in 3, the stage 3 in 1, and stage 4 in 1. The stage 3 pattern was seen in 1 case with a 80% reduction of FLAD (Fig. 7). Other 2 cases with a 80% reduction and 1 case with a 90% reduction of FLAD revealed frank systolic bulging with or without early diastolic shortening (Fig. 8). In all 5 cases, complete occlusion of LAD for 5 min introduced the stage 4 pattern of myocardial segment shortening in the ischemic area (Table I).

DISCUSSION

The recognition of the asynergy of the left ventricle has become very important for the evaluation of ventricular function and prognosis in the patients with ischemic heart disease. Clinically, cineventriculography is widely used according to the classification of the asynergic movement of the left ventricle by Herman et al.¹⁴⁾ For the documentation of the relative or reversible ischemic zone, stress cineventriculography has been examined.¹⁵⁾ Our study was directed to be a basis of the analysis of cineventriculography from the

Fig. 7. Stage 3 pattern in a case with a 80% reduction in FLAD.

mechano-biochemical standpoint. Measurement of myocardial segment length had been done by the mercurly-in-Silastic tubing segment length gauge or very soft strain gauge arch. Both of the transducers were not enough compliant, not to distort the diastolic shape of left ventricle. In this meaning, ultrasonic crystals can be the best transducer.

Regional myocardial function has been widely studied by means of a Walton-Brodie strain gauge arch,¹⁶⁾⁻¹⁹⁾ which measures isometric developed tension. What was measured by this method, however, was very confusing. As Lewantowski et al²⁰⁾ pointed out, the force measured by the strain gauge arch was a difference between the developed force under the arch and the force developed by surrounding myocardium. When the change in preload affected ventricular diameter, this difference would not reflect the change in the developed force under the arch. We have shown that the force measured by this method could represent myocardial contractility when left atrial pressure was kept constant.²⁰⁾ Therefore, Yoshida's study²¹⁾ in which the changes in contraction force of ischemic left ventricle was measured by this method during coronary obstruction would be incorrect, although left ventricular end-diastolic pressure was not changed markedly.

Fig. 8. Stage 4 pattern in a case with a 90% reduction in FLAD.

Table I. The Relationship between Percent Reduction in Coronary Blood Flow and Pattern of Segment Length

Pattern of Segment Length	Percent Reduction in Coronary Flow						
	0%	20%	40%	60%	80%	90%	100%
Type 0	14	3					
I		1	1	2			
II				3			
III				1	1		
IV				1	2	1	5
Total	14	4	1	7	3	1	5

In this respect, direct measurement of myocardial segment length using an ultrasonic dimension gauge appears an ideal approach to the evaluation of regional myocardial function.

Concerning the course of bulge formation, our data was very similar not only to the data presented by Theroux et al,²²⁾ but also to other data which were obtained by technically incomplete method to measure segment length. It was very interesting that the duration of ischemia had a similar effect of

grade of reduction of coronary flow upon myocardial segment shortening. The explanation of this similarity was remained in further investigation.

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