Behavior of Asynergic Ventricle

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SUMMARY

Effect of increased left atrial pressure and a positive inotropic agent upon asynergic left ventricle which was produced by acute occlusion of LAD were examined in 8 open-chest dogs. Systolic bulging in ischemic area was qualified by ESL/EDL in percentage. Left atrial pressure was controlled by the reservoir connected to left atrial appendage with a large bore tubing. Cardiac output and aortic pressure were decreased following coronary occlusion without change in isometric developed tension in nonischemic area of left ventricle. Increase of left atrial pressure from 5 mmHg to 14 mmHg produced rise in stroke volume to 191% and rise in aortic pressure to 156% in asynergic left ventricle respectively. These increases were not accompanied by change in ESL/EDL.

Therefore, extracardiac factors were assumed to explain the prominent increase in left ventricular stroke work by elevation of left atrial pressure in asynergic left ventricle. Isoproterenol enhanced total cardiac performance by increasing the function of nonischemic area without deteriorous effect on the ischemic area.

Additional Indexing Words:

Coronary occlusion Systolic bulge Segment length Isometric tension Preload Isoproterenol

SINCE Tennant and Wiggers¹⁾ showed that acute occlusion of coronary artery produced systolic bulging of the ischemic myocardium in 1935, sequestration of the blood into the systolic bulge has been believed to be at least one of the main causes of deterioration of left ventricular function by acute myocardial infarction. The time dependent improvement of ventricular function following acute episode of myocardial infarction has been demonstrated relating to change in ventricular compliance by several investigators,^{2),3)} however, the relationship between contractility of uninvolved myocardium and mechanical behavior of ischemic myocardium has not been clear. An understanding of the effects of various therapeutic approaches designed to improve ventricular function on ischemic myocardium could have clinical

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importance. The purpose of the present study is to reveal the effects of increased left atrial pressure and positive inotropic agent upon asynergic left ventricle.

METHOD

Eight mongrel dogs weighing 15–20 Kg were anesthetized with sodium pentobarbital in an initial dose of 30–40 mg/Kg. Thoracotomy was performed in the fifth left intercostal space under the artificial respiration by a Harvard pump. The left anterior coronary artery (LAD) was dissected about 4 cm below the bifurcation of the main segment for the passage of a ligature around the vessel. Aortic blood flow was measured with a squarewave electromagnetic flowmeter. Ascending aortic blood pressure was measured through a catheter. Left ventricular pressure was measured through a short polyethylene cannula which was inserted into the left ventricular cavity via apex and attached directly to a pressure transducer. The first derivative of left ventricular pressure (dp/dt) was obtained electrically. A reservoir filled with normal saline was connected to the left atrial appendage with a large bore tubing in order to keep left atrial pressure constant during each experimental procedure. Left atrial pressure was measured through a catheter. Left ventricular segment length was measured by the use of prongs which measured displacement through a strain gauge. Segment length measurements were made adjacent to LAD in the direction perpendicular to the course of LAD. Local isometric force of the left ventricle was measured by the use of small-sized strain gauge arch. The arch was sutured to the superficial layer of the myocardium in the direction parallel to the left circumflex coronary artery (CX), with stretching the

Fig. 1. Schema of the presentation.
Ao: Aorta, LV: left ventricle, LA: left atrium, PA: pulmonic artery.

resting muscle length by approximately 20% (Fig. 1). Transient occlusion of LAD artery produced grossly ischemic myocardium which was supplied by this vessel. We chose this area for the suturing site for prongs, and reconfirmed by repeated transient occlusion. The rest of the myocardium of the free wall of left ventricle was confirmed non-involved by this maneuver, and the strain gauge was applied.

Effects of increased left atrial pressure from about 5 mmHg to 14 mmHg on left ventricular function were examined in control state and 3 min after occlusion of LAD. On asynergic left ventricle, effect of a positive inotropic agent was tested by continuous infusion of isoproterenol intravenously. Data were recorded when heart rate was increased up to 115% of control state at left atrial pressure of about 5 mmHg and 14 mmHg respectively.

Regional myocardial function of non-ischemic area was represented by isometric developed tension. When left atrial pressure was changed in each experimental maneuver, tension measured by strain gauge arch could be modified by the change in tension of surrounding myocardium,⁴⁾⁻⁶⁾ therefore, isometric developed tension should be evaluated in comparison with data taken at the same left atrial pressure. Systolic bulging in ischemic area was quantified by end-systolic length/end-diastolic segment length (ESL/EDL) in percentage. End-diastolic pressure-length relationship was shown as following calculation⁷⁾:

$$K = \frac{\Delta P}{\Delta L/EDL_5 \times 100} \text{ mmHg in } \Delta EDL$$

where K=slope of the pressure-length relationship. ΔP =changes in left atrial pressure (from about 5 mmHg to 14 mmHg). ΔL =changes in EDL. EDL_5 =EDL at left atrial pressure of about 5 mmHg.

RESULT

Effect of increase in left atrial pressure on intact and regionally ischemic left ventricle:

Table I. Effect of Occlusion of LAD on Intact Ventricle

		P _{LA}	SV	LV dp/dt	P _{AO}	HR	EDL	ESL/ EDL	Tension	K
Control	A	4.6 ±0.5	12.3 ±3.7	1,380 ±170	120±16	146±11	6.21 ±0.36	92.7 ±4.3	18.7 ±5.2	0.750 ±0.178 ↑ NS ↓ 0.682 ±0.281
	B	14.0 ±0.7	21.8 ±7.1	1,652 ±165	140±18	144±11	7.04 ±0.56	86.2 ±5.6	15.7 ±2.9	
LAD occlu- sion	C	4.9 ±0.3	8.7 ±3.5	784 ±145	71±12	146±19	6.38 ±0.34	102.7 ±1.7	17.6 ±6.2	
	D	14.0 ±0.7	16.6 ±5.5	1,140 ±230	111±12	147±17	7.39 ±0.67	102.3 ±1.2	16.1 ±3.7	
P	A : B	<0.001	<0.001	<0.001	<0.001	NS	<0.001	<0.001		
	A : C	NS	<0.001	<0.001	<0.001	NS	<0.001	<0.001	NS	
	B : D	NS	<0.001	<0.001	<0.001	NS	<0.001	<0.001	NS	
	C : D	<0.001	<0.001	<0.001	<0.001	NS	<0.001	NS		

Table I showed changes in hemodynamic parameters of the left ventricle produced by occlusion of LAD at 5 mmHg and 14 mmHg of left atrial pressure. In intact left ventricle, EDL was stretched to 113% in mean value, stroke volume was increased to 177% and aortic pressure was elevated to 117% of control value by increase in left atrial pressure from 4.6 mmHg to 14 mmHg. After occlusion of LAD, aortic pressure, maximum LV dp/dt and stroke volume were dropped markedly without the change in heart rate, and isometric developed tension in uninvolved area were unchanged. In ischemic area, EDL were prolonged slightly but significantly by 2.8% and 4.9% at left atrial pressure of 4.9 mmHg and 14 mmHg respectively. Nevertheless stiffness of the left ventricular wall in ischemic area presented by K decreased in 4 cases and increased in 4 cases. Systolic bulging in ischemic

Fig. 2. The representative recordings of hemodynamics following occlusion of LAD.

area was completed within 1 min after coronary occlusion (Fig. 2). This systolic lengthening of the ischemic myocardium was unchanged and ESL/EDL was also unchanged statistically by increase in left atrial pressure. Increase of left atrial pressure produced rise in stroke volume to 191% and rise in aortic pressure to 156% in asynergic left ventricle.

Effect of isoproterenol on asynergic left ventricle (Table II):

Infusion of isoproterenol which increased heart rate up to 115% resulted in increase of stroke volume, but did not change aortic pressure at both levels of atrial pressure. Therefore, this increment of stroke volume was due to increase in contractility which was shown by increase in isometric developed tension of uninvolved myocardium. Isoproterenol did not change ESL/EDL in ischemic myocardium and stiffness of the ischemic left ventricular wall (K), while shortening of EDL of ischemic area occurred slightly but significantly. Effect of increased left atrial pressure on stroke work in asynergic left ventricle during infusion of isoproterenol was more prominent than that in normal ventricle.

DISCUSSION

The changes in local myocardial function following coronary occlusion have been studied by many investigators,⁴⁾⁻¹⁰⁾ employing a variety of techniques. In the use of the strain gauge arch to measure the local forces in the ischemic left ventricular wall, it was pointed out that the indirect effect of the surrounding normal tissue on the gauge could importantly affect the measurement

Table II. Effect of Isoproterenol on Asynergic Ventricle

		P _{LA}	SV	LV dp/dt	P _{AO}	HR	EDL	ESL/ EDL	Tension	K
LAD occlusion	C	4.9 ±0.3	8.7 ±3.5	784 ±145	71±12	146±19	6.38 ±0.34	102.7 ±1.7	17.6 ±6.2	0.682
	D	14.0 ±0.7	16.6 ±5.5	1,140 ±230	111±12	147±17	7.39 ±0.67	102.3 ±1.2	16.1 ±3.7	±0.281 ↑ NS
LAD occlusion with Isoprote- renol	E	4.8 ±0.6	10.8 ±3.4	1,030 ±265	73±12	170±10	6.15 ±0.30	103.7 ±2.1	21.4 ±6.7	↓ 0.635
	F	13.9 ±0.6	21.5 ±5.7	1,562 ±191	113±9	173±5	7.21 ±0.68	102.9 ±1.3	22.6 ±4.9	±0.283
P	C : D	<0.001	<0.001	<0.001	<0.001	NS	<0.001	NS		
	C : E	NS	<0.001	<0.001	NS	<0.001	<0.01	NS	<0.001	
	D : F	NS	<0.001	<0.001	NS	<0.001	<0.05	NS	<0.001	
	E : F	<0.001	<0.001	<0.001	<0.001	NS	<0.001	NS		

of force within an ischemic area.⁴⁾⁻⁶⁾ When bulging of the ischemic myocardium is the object of investigation, segmental lengthening of the ischemic myocardium should be recorded. Almost all studies used a mercury-in-silastic tubing gauge for measuring segmental length of the myocardium.⁷⁾⁻⁹⁾ We have published previously the effect of change in afterload upon ischemic bulge in comparison to left ventricular hemodynamics and have emphasized the importance of pressure-length relationship in ischemic myocardium.¹²⁾ Many investigators discussed the characteristics of the ischemic regional myocardium by the method of pressure-length loop.^{8),11),13)}

The contractile characteristics of non-ischemic myocardium after coronary occlusion have not been clear, because so many factors affected the contractility. Wyatt et al¹⁴⁾ revealed that depression of left ventricular function after coronary occlusion might be partially related to depression of function in apparently "non-ischemic" myocardium by analysing the systolic shortening of the regional myocardium against left ventricular end-diastolic pressure which was controlled arbitrarily. In this experiment, we minimized the change of left ventricular volume by which measurement of isometric developed tension was affected and showed no significant change in non-ischemic myocardial contraction after coronary occlusion.

But we could not conclude that depression of left ventricular function after coronary occlusion was only due to loss of contractility and systolic bulging in ischemic myocardium. The effect of increase in preload on stroke work after coronary occlusion was more prominent than that in control state, and the paradoxical expansion of the ischemic myocardium was not increased by elevation of left atrial pressure after coronary occlusion. Moreover, isometric developed tension in the nonischemic myocardium was not altered by coronary occlusion. These results suggested that extracardiac factors -e.g. systemic vascular resistance and circulatory blood volume have played important roles in this situation.

Puri and Bing¹⁵⁾ have represented that the ischemic zone showed an increase in the amplitude of paradoxical systolic expansion, although the non-ischemic myocardium responded to drugs like norepinephrine, metaraminol and isoproterenol in a normal manner. Our previous study could show an increase in the amplitude of systolic bulge in ischemic muscle by increment of afterload,¹²⁾ but in the present study, neither an increase in preload, nor an administration of isoproterenol could produced an increase in the amplitude of systolic bulge.

Therefore, we concluded that isoproterenol enhanced total cardiac performance by increasing the function of non-ischemic area without deteriorous effects on the ischemic area, when aortic pressure was not increased significantly.

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