Postoperative assessment of left ventricular function

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The evaluation of left ventricular function in man by invasive means presently is accomplished by two major techniques. First, the recording of left ventricular pressure and second, the performance of left ventriculography. Although some of the parameters derived from these techniques are based upon current concepts of myocardial muscle mechanics and others assess characteristics of left ventricular performance, all methods have both theoretical and practical limitations. In general, it can be said that resting measurements of contractile indexes such as V max, Max dp/dt at developed pressure, Vcf and mean systolic ejection rate have proven to be an insensitive way to assess dysfunction except when the impairment is advanced. Measurement of these indexes during exercise may prove more sensitive and is presently being evaluated. The ejection fraction and regional wall motion studies have demonstrated improvement of ventricular performance after bypass surgery when ejection fraction is depressed and regional wall motion abnormalities represent hypokinetic as compared to akinetic areas.

Our largest experience and emphasis since the beginning of bypass surgery have been the assessment of left ventricular performance under various types of stress, such as increased afterload, volume loading, angiographic stress, handgrip, atrial pacing, and exercise. I believe that the most sensitive and rewarding relate to the stress of exercise and particularly the use of ventricular performance curves. Starling left ventricular function curves define the relationship between the left ventricular stroke work index on the vertical axis and left ventricular end-diastolic pressure on the horizontal axis. A family of functional curves can then be drawn at rest and during the increasing stages of exercise with the patient serving as his own control before and after surgery. Thus one can assess whether performance is depressed, abnormal though improved, entirely normal, or worse. It is well recognized that as with the other techniques, there are also limitations to the use of left ventricular end-diastolic pressure as a predictor of end-diastolic volume. Definitive characterization of left ventricular function would require simultaneous measurements of end-diastolic pressure, end-diastolic volume, and stroke volume during the exercise. These are difficult measurements during exercise although a little easier to obtain today. Despite the occasional limitations, however, ventricular function curves in the clinical setting presented at this meeting where intravascular volumes are normal, ventricles are not chronically dilated, and cardiac output not depressed, elevations of left ventricular end-diastolic pressure most often relate to impaired left ventricular performance or to a change in the normal ventricular pressure volume relationship. When assessing the results of coronary bypass, difficulty in distinguishing compliance from volume change would generally result in an underestimation of the degree of improvement. The most dramatic hemodynamic change noted following bypass surgery is reduction in left ventricular end-diastolic pressure during exercise. From the patient's standpoint, over and above the relief of angina, this reduction of end-diastolic pressure may allow improved exercise tolerance, regardless of whether it represents compliance or volume change. Two examples of such change following bypass will illustrate what can occur. These examples were taken from an early pilot study, 28 patients studied before surgery, 6 weeks after, and 1 year after surgery, in order to evaluate serial changes of cardiac function as affected by surgery, myocardial infarction, etc. The first example (*Fig. 1*) represents a patient with angina and severe coronary disease but with normal left ventricular contraction. In the figures at the top, left ventricular end-diastolic pressure rose abnormally during work preoperatively. Six weeks after surgery, the

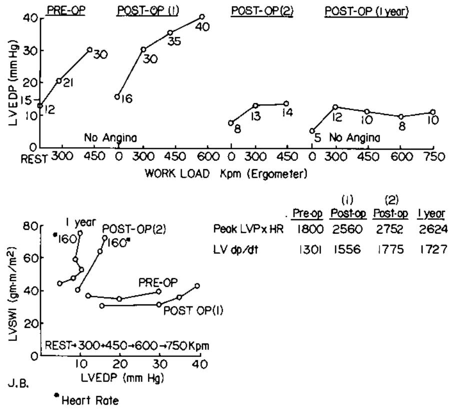
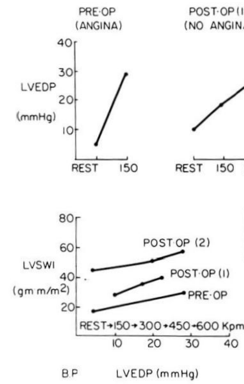


Fig. 1. Angina and severe coronary disease with normal left ventricular contraction.

left ventricular end-diastolic pressure during exercise again rose abnormally similar to that before surgery. Subsequent angiographic study demonstrated graft closure and for that reason he underwent reoperation. The third set of figures now demonstrate that his end-diastolic pressure remains normal during exercise following the second operation. Again, 1 year later, we see that even at much higher work loads, higher dp/dt, higher heart rate and blood pressure, his end-diastolic pressure remained entirely normal. Looking at ventricular performance curves and the figures at the bottom, we see the two curves before and after the unsuccessful first surgery are depressed, whereas in the study early and 1 year after his second successful operation, the ventricular performance curves are within the normal range. This illustrates the importance of adequacy of revascularization with the results closely related to graft patency. It also demonstrates that these results are noted soon after surgery and persist at later study if the adequacy status remains the same.

A second patient illustrates an additional important point. This patient also has had bypass surgery, his grafts are open, revascularization was judged adequate, but he has significant impairment or scar within his left ventricle. In the figures at the top, note that the end-diastolic pressure rises abnormally during exercise before surgery and still rises abnormally after surgery even though it is not as high (*Fig. 2*). This is again illustrated 1 year later. Looking at his function curves in the figures at the bottom we see before surgery a depressed curve. Six weeks and 1 year after surgery, it has improved with regard to the stroke work and end-



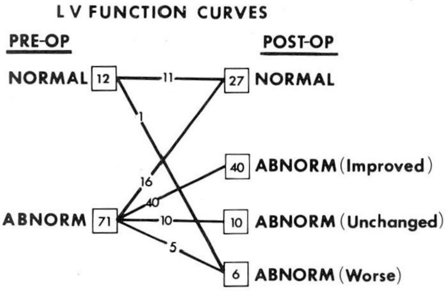
	Pre·op	Post·op 1	Post·op 2
Peak LVP x HR	2100	1920	2296
LV dp/dt	980	1120	1666

Fig. 2. Impairment or scar within left ventricle.

diastolic pressure, although the latter remains abnormally elevated during exercise and the curves remain flat. The important factor here appears to be the degree of scar within the left ventricle.

To confirm these findings, a larger study was designed. This involved 83 patients with stable angina and severe coronary artery obstruction. There were no aneurysms, valve disease, or congenital disease. All patients were studied before surgery and 12 to 14 months postoperatively, and all studies were prior to angiography. They were controlled for medications at the time of both studies. Exercise was performed on a bicycle ergometer in the supine position with progressive increments of work. These findings were then correlated with the clinical and angiographic findings. It is noteworthy that 87% of the patients had two- or three-vessel disease (over 70% obstruction). Ventricular classification (angio) revealed Class I (normal) 35%, Class II (2 areas) 33%, Class III (3 areas) 15%, Class IV (4 areas) 15%.

The question arises of how often changes in ventricular performance occur after bypass surgery. These possibilities are outlined in *Figure 3*. Those whose curves were normal be-



TOTAL	IMPROVED	UNCHANGED	WORSE
83 100%	67 (27) 81% (32)	10 12%	6 7%

Fig. 3. Changes in ventricular performance after bypass surgery.

fore surgery may remain normal although one patient became abnormal, associated with infarction in the perioperative period. Of those that are abnormal, some became normal, others improved although they were still abnormal, and some remained identically the same. A few became worse as a result of graft closure and myocardial infarction. Note the overall results at the bottom. In parentheses, under the improved group, is the number that is now entirely normal. Whether one has these results or other findings will depend on the characteristics of the group being studied, particularly with regard to the amount of scar already in the left ventricle.

The importance of this scar is illustrated by *Figure 4*. Note that highest percentages of improved ventricular performance curves are noted in patients who have the least scar, whereas the unchanged performance curves are most often in those individuals with the greatest amount of scar.

The second factor is that of adequacy of revascularization as illustrated in *Figure 5*. Adequacy was determined by graft status and/or by vessels that could not be bypassed. On the vertical axis, the percent of patients improved and on the horizontal axis, the amount of scar. Note that in the first two columns where the amount of scar is small and good revascularization has been achieved, the percent with improved left ventricular function curves is very high. This percent falls off in the middle two columns where graft patency and adequacy of revascularization is not as good. The final two columns demonstrate that when the amount of scar is considerable, this factor becomes so overriding that the effects of adequacy of revascularization can no longer be noted. Finally, whether the graft used was a vein or mammary artery, bypass made no difference to these results on ventricular performance.

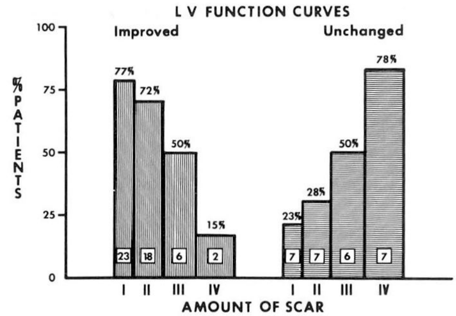


Fig. 4. Left ventricular performance in relation to amount of scar.

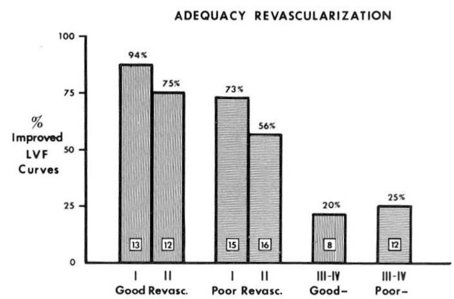


Fig. 5. Adequacy of revascularization.

Conclusion

(1) Postoperative ventricular performance appears directly related to (a) the degree of left ventricular impairment or the amount of scar and (b) the adequacy of revascularization (graft status). (2) With regard to the amount of scar, striking improvement was noted with only mild contraction abnormalities, less frequently in those who had moderate to severe abnormalities, and deterioration was frequent in the few patients who suffered postoperative myocardial infarction. (3) With regard to adequacy of revascularization, improvement in performance curves was demonstrated in patients with patent grafts and all disease bypassed regardless of graft type, less frequently where the grafts closed or disease could not be bypassed, and least frequently in groups with moderate to severe scar regardless of adequacy status. (4) In evaluation of left ventricular performance before and after coronary surgery, regional wall motion and ejection fraction remained important, especially in choosing patients for surgery. It would appear, however, that left ventricular performance curves during exercise are the most sensitive in evaluating the result.