

Left ventricular scars

Clinical and haemodynamic results of excision

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Thirty-six patients having coronary artery disease with scars occupying at least 10 per cent of the left ventricular internal surface area were followed from one to three and a half years after excision of the scar with or without a revascularization procedure. The operative mortality was 19.4 per cent and the late mortality was 30.6 per cent. Of the survivors, 15 patients (41.7% of the total group of patients) are improved by operation and 3 (8.3%) are unchanged or worse. All patients, regardless of whether their principal complaints were dyspnoea or angina, showed evidence before surgery of left ventricular dysfunction. No haemodynamic measurement was of value in predicting the results of surgery. The presence of moderately severe mitral regurgitation was associated with a poor prognosis. Patients improving after operation tended to have severe occlusive disease in no more than 1 vessel, while patients who failed to improve tended to have severe occlusive disease in 2 or more vessels. Nevertheless, the overlap was great enough that no reliable prognostic indices can be said to exist at present.

Approximately 4 to 20 per cent of patients who have had a myocardial infarction will develop a thin-walled scar which can be classified at necropsy as an aneurysm (Abrams *et al.*, 1963; Johnston, Lam, and Wright, 1969; Dubnow, Burchell, and Titus, 1965; Schlichter, Hellerstein, and Katz, 1954). The incidence of akinetic and dyskinetic scars detected angiographically in patients with healed myocardial infarctions is somewhat higher (Gorlin, Klein, and Sullivan, 1967; Cheng, 1971). Symptoms, when present in patients with large scars of the left ventricle, are predominantly angina pectoris and exertional dyspnoea (Johnston *et al.*, 1969; Schlichter *et al.*, 1954; Gorlin *et al.*, 1967; Davis and Ebert, 1972; Cooley and Hallman, 1968; Kluge *et al.*, 1971). Less frequently, recurrent ventricular arrhythmias or peripheral emboli from fragments of clot in the scar are encountered (Abrams *et al.*, 1963; Dubnow *et al.*, 1965; Schlichter *et al.*, 1954; Cooley and Hallman, 1968; Kluge *et al.*, 1971; Hazan

et al., 1973). It is common in symptomatic patients with ventricular scars to find extensive coronary artery occlusive disease, not only in the vessel supplying the infarcted area, but in other arteries as well (Dubnow *et al.*, 1965; Davis and Ebert, 1972). Since ventricular scars are now amenable to surgical excision (Lillehei *et al.*, 1962; Effler *et al.*, 1963; Cooley, Hallman, and Henly, 1964), a procedure which may be combined with some form of myocardial revascularization (Tice, Cheng, and Dolgin, 1970; Lillehei *et al.*, 1969; Favalaro *et al.*, 1968; Graber *et al.*, 1972; Ibarra-Perez and Lillehei, 1969), it is important to distinguish preoperatively those patients who will improve as a result of surgery from those whose scar is just one manifestation of extensive, irreversible coronary artery disease and who will not be helped by surgery.

This paper has two major objectives. The first is to review our surgical experience with 36 patients who had excision of ventricular scars, including a postoperative follow-up period ranging from one to three and a half years. The second objective is to review the preoperative haemodynamic and angiographic data in the light of available postoperative clinical and haemodynamic information to determine

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whether any prediction can be made of which patients will improve as a result of surgery.

Subjects and methods

Thirty-six patients who had excision of ventricular scars are included in the study. All scars occupied at least 10 per cent of the internal surface area of the left ventricle. Anatomically these ventricular scars were thinned areas of the ventricular wall consisting of fibrous tissue, usually interspersed with islands of normal or abnormal appearing cardiac muscle. Angiographically the scars appeared as akinetic or dyskinetic segments of the ventricular wall (Gorlin *et al.*, 1967). No hypokinetic segments were excised in this series of patients. All patients were men ranging in age from 36 to 75 years. All but 2 patients had right heart catheterization and all but 3 had measurements of cardiac output by indicator dilution or Fick technique. The 22 patients studied in the cardiopulmonary laboratory of our institution had measurement of left ventricular volume, ejection fraction (Davila and Sanmarco, 1966; Kennedy, Trenholme, and Kasser, 1970), and mean circumferential fibre shortening rate at the equator of the left ventricle (Karliner *et al.*, 1971). Left ventriculograms were recorded on 35 mm film running at 64 frames/second. Patients were in the 45° right anterior oblique position. Contrast medium (Renografin-76), 35 to 60 ml, was injected by a power injector either directly into the left ventricle or into the pulmonary artery. End diastole and end ejection were subsequently traced from the projected cine films with the aid of an Electronics for Medicine cine trace recording of the electrocardiogram. The volumes reported are the average of the first 1 to 3 beats during which the chambers were completely opacified. Premature beats and the first beat after a premature systole were not measured. No patient had atrial fibrillation at the time of the study. For 17 studies in which the ventricular volumes reported are the average of 2 or 3 successive beats, the average deviation for end-diastolic volume from the mean reported value is 1.9 ± 1.6 per cent and the average deviation of end-systolic volume is 2.7 ± 1.7 per cent.

The ventriculograms of the remaining 14 patients were done in other institutions, and it was not possible for us to correct for x-ray magnification. Accordingly, ventricular volume could not be measured, but ejection fraction and mean circumferential fibre shortening rate (expressed in circumferences per second), which are relative figures, could be measured without correction for magnification. Since the scar often involved the equator of the left ventricle, the level at which mean circumferential fibre shortening velocity (VCF_e) is measured, this value is not necessarily representative of the performance of the entire left ventricle in these patients. The basal part of the ventricle was involved by scar in only one patient. In order to assess the contractile performance of the ventricular muscle uninjured by scar the circumferential fibre shortening velocity at a level one-quarter of the way down from the base of the ventricle (VCF_b) was measured in 32 patients. In a pooled series of 21 patients without scars and with normal ventricular contractility, no statistically significant difference

was found between basal and equatorial VCF (1.30 ± 0.31 vs 1.41 ± 0.42 circ/sec). The size of the scar was measured by the method of Klein, Herman, and Gorlin (1967) and expressed as a percentage of the left ventricular internal surface area. Selective coronary arteriography was performed by the technique of Judkins (1967) or Sones and Shirey (1962) in all patients but one who had a severe allergic reaction to the contrast medium at the time of ventriculography. Three patients had ventricles so large that they were not completely visualized in a single cine frame and in these scar size could not be measured.

The surgical procedures done were excision of the scar alone in 13 patients, excision of the scar plus 1 aorta-coronary artery saphenous vein bypass graft in 9, excision of scar plus 2 bypass grafts in 9, excision of scar plus 3 bypass grafts in 1, excision of scar plus mitral valve replacement in 1, excision of scar plus Vineberg procedure in 1, excision of scar plus 2 bypass grafts and a tricuspid annuloplasty in 1, and excision of scar plus 1 bypass graft and a pulmonary thrombectomy in 1. The technical details of the ventricular surgery have been described previously (Tice *et al.*, 1970). A postoperative medical history was obtained from all 29 patients who were discharged from the hospital and records of all interim periods in hospital were reviewed. Whenever possible patients were re-examined by a cardiologist and had repeat chest x-rays and electrocardiograms. Sixteen patients were recatheterized between 4 months and 3 years after operation.

Results

When patients were divided into 3 groups according to whether the left ventricular scar was dyskinetic,

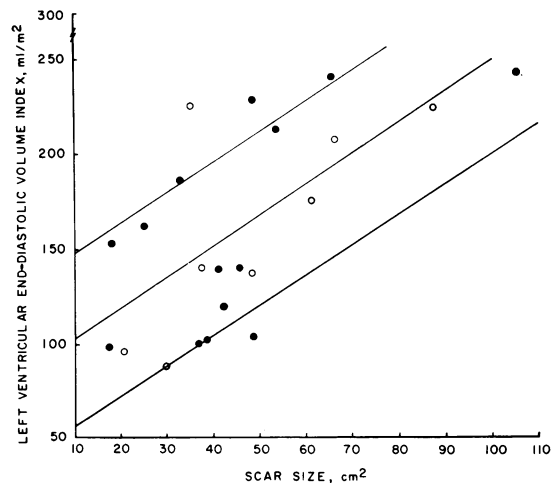


FIG. A plot of scar size in cm^2 against left ventricular end-diastolic volume index. The open symbols refer to patients who improved after operation and the solid symbols to patients who failed to improve or who died. The 3 lines are the regression line ± 1 standard error of the estimate ($r = 0.648$; $P < 0.01$).

akinetic, or presented both features, the average age, left ventricular end-diastolic pressure, mean pulmonary artery pressure, cardiac index, left ventricular end-diastolic volume index, left ventricular ejection fraction, basal and equatorial VCF, and per cent of left ventricular internal surface area occupied by scar did not differ significantly between groups (Table 1). All patients showed some evidence of compromised left ventricular function. As absolute scar size increased, left ventricular end-diastolic volume index tended to increase (Fig.) There was also an inverse relation between the end-diastolic volume index and the ejection fraction. The severity of the major coronary artery lesions

did not appear to differ among the 3 groups. Six patients had mitral regurgitation of moderate severity, and all but one of these had dyskinetic scars.

The clinical results of surgery for the 3 groups are summarized in Table 2. Patients are subdivided into 4 categories depending upon whether they were clinically improved by the surgery, remained in the same or a poorer clinical state, died in the hospital, or died after discharge. Clinical improvement is taken as a reduction in the frequency of anginal attacks at preoperative levels of activity or an increase in the amount of exertion which could be tolerated without dyspnoea. No attempt has been made to quantitate further these subjective

TABLE 1 Haemodynamic features according to scar type

	Dyskinetic	Akinetic	Combined dyskinetic and akinetic
Age of patient (yr)	52.7 ± 8.9	47.8 ± 5.4	50.4 ± 7.8
Number of patients	19	10	7
LV end-diastolic pressure (mmHg)	21.6 ± 6.7	23.4 ± 10.3	17.3 ± 8.2
Mean PA pressure (mmHg)	31.7 ± 13.2	27.2 ± 8.7	24.0 ± 7.9
Cardiac index (l./min per m ²)	2.32 ± 0.54	2.51 ± 0.87	2.45 ± 0.60
LV end-diastolic volume index (ml/m ²)	173.9 ± 47.1	169.0 ± 62.9	134.7 ± 55.1
LV ejection fraction	0.209 ± 0.076	0.288 ± 0.127	0.218 ± 0.155
Equatorial VCF(circ/sec)	0.308 ± 0.162	0.298 ± 0.192	0.304 ± 0.147
Basal VCF(circ/sec)	0.650 ± 0.382	0.644 ± 0.292	0.573 ± 0.303
Per cent scar	20.63 ± 8.45%	18.65 ± 8.86%	21.48 ± 6.49%

TABLE 2 Clinical results of surgery according to type of scar and preoperative symptoms

Type of scar	Improved		Unchanged		Hospital death		Late death		Total No.
	No.	%	No.	%	No.	%	No.	%	
Dyskinetic	9	47.4	1	5.3	3	15.8	6	31.5	19
Akinetic	5	50.0	1	10.0	2	20.0	2	20.0	10
Combined dyskinetic and akinetic	1	14.3	1	14.3	2	28.6	3	42.8	7
<i>Symptoms</i>									
Angina	8	50.0	1	6.2	1	6.2	6	37.5	16
Dyspnoea	4	50.0	1	12.5	2	25.0	1	12.5	8
Angina and dyspnoea	3	25.0	1	8.3	4	33.3	4	33.3	12

TABLE 3 Clinical results in relation to type of surgery

Type of surgery	Improved		Unchanged or worse		Dead		Total No.
	No.	%	No.	%	No.	%	
Aneurysmectomy	6	46.2	2	15.4	5	38.5	13
Aneurysmectomy + 1 bypass	4	44.4	1	11.2	4	44.4	9
Aneurysmectomy + 2 bypasses	3	33.3	0	0	6	66.7	9

responses of the patients. All deaths were due to cardiovascular causes, usually myocardial infarction or heart failure. No patient classified as a late death was improved clinically after discharge from the hospital. There was no difference between the success and failure rates of the groups with dyskinetic or akinetic scars alone. The lowest percentage of successes and highest percentage of deaths was in the group with scars having both dyskinetic and akinetic properties. There are, however, only 7 patients in this group so the figures may be misleading. Of the 6 patients with moderately severe mitral regurgitation, 4 died in the hospital and 1 is unimproved by surgery. None of these patients had mitral valve surgery.

The patients can also be grouped according to their predominant presenting complaint. Sixteen patients presented for angina pectoris alone, 8 for exertional dyspnoea, and 12 for both angina and dyspnoea (Table 2). There was no significant difference in the haemodynamic measurements or the per cent of left ventricle occupied by scar between the 3 groups. Improvements occurred in 50 per cent of the group with angina only, though 43.8 per cent of this group died within the follow-up period and 1 patient (6.2%) was unimproved by surgery. The group with dyspnoea had the same percentage of improved patients, 12.5 per cent unchanged by surgery and 37.5 per cent deaths. Patients with both dyspnoea and angina had fewer improvements than the other 2 groups (25.0%) and had the highest percentage of deaths (66.7%). Overall, only 41.7 per cent of all patients could be considered to be improved, while 50.5 per cent had died within the follow-up period. The median survival time of those patients who died after discharge was 6.0 months (mean 8.3 ± 5.9 months). Seven patients died during the postoperative hospital stay (19.4% hospital mortality), while the remaining patients died between 3 and 20 months after surgery.

The clinical results were also evaluated in relation to the type of operation performed (Table 3). Aneurysmectomy alone and aneurysmectomy plus one bypass graft had essentially the same improvement rate but a slightly higher percentage of deaths occurred in those having a bypass graft. The lowest success rate and the highest hospital and late mortality were in those having aneurysmectomy plus 2 bypass grafts. In the group with only angina as the presenting complaint, 5 patients had aneurysmectomy alone and 4 of these improved despite the fact that no bypass graft was performed.

Since between one-quarter and one-half of the patients in the various groups benefited from the surgery, the data were analysed to determine which factors were most likely to be associated with a suc-

cessful outcome. In order to see whether a pattern emerged which would allow one to predict in advance the results of surgery, each of the 3 groups were subdivided into patients who improved as a result of surgery and those who failed to improve or died. The group with combined dyskinetic and akinetic scars was not analysed, since it contained only one patient who improved. In the group with dyskinetic scars the average age of patients who improved was less than that of patients who failed to improve (44.0 ± 4.7 years vs 51.6 ± 2.7 years; $P < 0.02$). This is, however, the youngest subgroup in the entire series and its average age is significantly lower than that of the group of patients with dyskinetic scars who benefited from surgery (51.0 ± 2.7 years; $P < 0.01$), so age alone cannot be considered an important variable in determining prognosis. No measured haemodynamic variable differed significantly in either group between patients who improved and those who failed to improve.

Sixteen patients were restudied by cardiac catheterization. Cardiac index, left ventricular end-diastolic pressure, and left ventricular end-diastolic volume index did not vary significantly from the preoperative values. Ejection fraction tended to rise and was significantly increased postoperatively for patients with angina. Considering the haemodynamic data for the individual patients, 6 showed improved values, 4 were unchanged, 3 were worse, and 3 had incomplete preoperative or postoperative values. In 10 of the 13 patients with adequate data there was good correlation between the postoperative clinical state of the patient and the postoperative haemodynamic data even when the preoperative complaint was angina pectoris. There was an apparent trend for a decrease in left ventricular end-diastolic pressure and a rise in cardiac index in those who improved, and a change in the opposite direction for those who failed to improve. The samples are small, however, and the differences between the preoperative and postoperative values are not statistically significant. Left ventricular ejection fraction for both groups rose, but in neither group is it statistically significant.

Four of the recatheterized patients had had a total of 6 bypass grafts in addition to aneurysmectomy. Two had one bypass graft and in each the graft was occluded. Both patients were unimproved by the surgery and one subsequently died. Two patients had 2 bypass grafts each and in both one of the grafts was found to be occluded. One of these patients was improved by the surgery, while the other was unimproved and died 16 months after surgery.

One of the patients who died in the immediate postoperative period and 3 who died subsequent to discharge had necropsies. Three of those patients

had 2 bypass grafts each and one had 3 bypass grafts. Each had occlusion of 2 grafts. Two of the patients had evidence of recent myocardial infarction and the other 2 had pulmonary emboli.

Discussion

The clinical and haemodynamic findings in this study are comparable to those of previous investigators (Abrams *et al.*, 1963; Schlichter *et al.*, 1954; Gorlin *et al.*, 1967; Cheng, 1971; Kluge *et al.*, 1971; Kitamura *et al.*, 1973). The hospital mortality of the group (19.4%) is quite similar to that which has been reported for several large series (Cooley and Hallman, 1968; Lillehei *et al.*, 1969; Favaloro *et al.*, 1968; Ibarra-Perez and Lillehei, 1969), though not as low as the 5.0 per cent mortality reported by Hazan *et al.* (1973).

Some of the published studies of left ventricular aneurysmectomy are limited to a description of the hospital course (Kluge *et al.*, 1971; Lillehei *et al.*, 1969) or to general statements of the post-hospital progress (Cooley and Hallman, 1968; Effler *et al.*, 1963; Ibarra-Perez and Lillehei, 1969). The largest of the reports giving more detailed information of the course after discharge is that of Favaloro *et al.* (1968). In this study of 80 patients selected for long-term follow-up (1 to 8 years), there were 12 hospital deaths (15.0%) and 19 late deaths (23.8%), for a total mortality of 38.8 per cent. This is quite comparable to the present series. The series of Hazan *et al.* (1973) reports a mortality of 15 per cent and failure rate of 20 per cent in a series of 20 patients with the poorest results occurring in the patients with heart failure as the indication for surgery (44.4% failures). In the series of Favaloro *et al.* (1968), 5 of the late deaths were from non-cardiac causes, while in our series all late deaths were related to the heart. Of the 18 survivors in the present series, 15 (83.3%) are asymptomatic or considerably improved by surgery, while 3 (16.7%) are unimproved or worse. In the series of Favaloro *et al.* (1968), 46 of the 49 survivors (94%) were symptom free or improved, and only 3 (6%) failed to benefit from the surgery. The combined results of the 2 studies suggest that patients who are discharged from the hospital after surgery fall into 2 groups. Those who are unimproved tend to deteriorate clinically and die within a short time, while those who improve tend to remain in a stable clinical state.

It is significant that 4 of 5 patients having just an aneurysmectomy, when angina was the principal complaint, were improved. Aneurysmectomy without coronary artery revascularization is most likely to benefit the patient if only the vessel supplying

the scar has a major occlusive lesion. This was the case in 2 of the 4 patients who improved. In the other 2, the additional major lesion was in a non-dominant circumflex artery and the dominant right coronary artery had good flow. An additional reason for improvement of angina might be a reduction in left ventricular size postoperatively and a concomitant fall in myocardial oxygen requirements. One patient who had pre- and postoperative left ventricular volume measurement showed a reduction in volume. The other 3 had a fall in left ventricular end-diastolic pressure, suggesting a decline in volume. The fifth patient who failed to improve had disease confined to the vessel supplying the area of the scar and the reason for the failure is unknown. This patient was not restudied postoperatively. Patients who required bypass surgery in addition to excision of the scar had significant disease in more than one vessel and the rate of improvement (36.4%) was much lower than that of patients who required only an aneurysmectomy.

Regardless of whether the presenting complaints were angina pectoris or dyspnoea, all patients had some evidence of compromised left ventricular function. In our study, as in that of Kitamura *et al.* (1972), patients who improve clinically tend to increase their cardiac indices and ejection fractions and reduce their left ventricular diastolic pressures and volumes. Patients who fail to improve tend to increase their left ventricular diastolic pressures and volumes and decrease their cardiac outputs, even though the left ventricular ejection fraction may improve. There was a great deal of individual variation among our patients, however, and none of these values reaches the level of statistical significance. This variability is also seen in the series of Schimert *et al.* (1970).

A consideration of the preoperative haemodynamic data in this series of patients in no way allows one to predict the clinical outcome of the surgery. Basal VCF, though higher than equatorial VCF, was reduced in all subgroups but was of no predictive value concerning the outcome of surgery. This is surprising since one might expect, as previous authors have suggested (Kluge *et al.*, 1971; Key, Aldridge, and MacGregor, 1968; Watson, Dickhaus, and Martin, 1972; Arthur, Basta, and Kioschos, 1972), that the contractility of the non-infarcted ventricular muscle might determine to a large degree the postoperative course of the patient. Two recent abstracts report that estimation of the ejection fraction of the non-scarred portion of the left ventricle correlates well with both mortality and clinical improvement (Watson *et al.*, 1972; Arthur *et al.*, 1972). The reason for the discrepancy between these reports and our findings is unclear.

Although ventricular volume tended to increase as the absolute size of the scar increased, we did not find the close correlation between the percentage of the ventricular surface area made up by scar and ventricular function which was predicted by Klein *et al.* (1967) and reported by Kitamura *et al.* (1972, 1973). This may be because of the extensive nature of the coronary arterial disease present in this group of patients which added to the dysfunction of the non-scarred portion of the ventricle.

The matter of the contribution of patent bypass grafts to the well-being of the patient was not systematically explored in this study, since graft patency was investigated at catheterization or necropsy in only 7 of the 21 patients having bypass grafts. The importance of bypass graft patency is suggested, however, by the fact that 5 of the 7 patients with occlusion of 1 or more of the grafts died and a sixth is unimproved by the surgery.

The incidence of severe, multiple vessel disease, as defined by either diffuse narrowing or narrowing of 75 per cent or more in 2 or more vessels, was quite high in this study (71.5%). The fact that 60 per cent of patients with severe involvement of only 1 vessel were improved by surgery, while only 40 per cent of the patients with severe involvement of 2 or more vessels benefited from the surgery, suggests that this may be the single most important factor in determining the results of aneurysmectomy (Favaloro *et al.*, 1968). On the other hand, 40 per cent of those with severe involvement of only 1 vessel failed to profit from surgery and 40 per cent of those with severe involvement of 2 or more vessels benefited from surgery. The presence of severe mitral regurgitation also adversely affects prognosis, though it is possible that replacement of the mitral valve in these patients might have altered the outcome. The sum total of factors that determine the surgical result still remains obscure. Since guidelines for the selection of patients for resection of left ventricular scars are still lacking almost a decade after aneurysmectomy became an accepted cardiac surgical procedure, it appears that a controlled series involving randomization of a large number of patients by co-operating institutions is needed to answer the question.

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