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Coronary By-pass Operation—Graft and Left Ventricular Function

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ABSTRACT

Of 121 patients surviving a by-pass operation 114 have been followed up hitherto. At first follow-up - usually one year after operation - the angina pectoris was relieved in 87% of the patients and in 85% at least one vein by-pass was patent. A high correlation was found between subjective result and graft patency. Advanced arterial changes at preoperative coronary angiography did not prevent good result after surgery. In about half of the patients whose pain was relieved, the left ventricular ejection fraction was increased postoperatively. However, in many patients, who were subjectively improved, the ejection fraction was unchanged or even decreased.

INTRODUCTION

Coronary angiography is a prerequisite for selection of patients before aorto-coronary by-pass surgery. Shunt angiography also is necessary for post-operative evaluation. The value of ejection fraction determination is still an open question, but no doubt, however, that valuable information concerning the functional state of the myocardium is attained preoperatively as well as post-operatively. With increasing experience ejection fraction determination will, hopefully, be attributed greater significance as a prognostic guide in selection of patients for surgery.

Several methods have been recommended for surgical treatment of angina pectoris. Reports from Sweden on the results of operation have included those (1, 4), who used Beck´s method and the Vineberg procedure, i.e. indirect revascularization, respectively.

During the last decade increasing interest has been focused on direct revascularization by a by-pass technique in which a vein is implanted between the aorta and the coronary artery distal to the occluded area (3).

When evaluating the results consideration must be paid to the total clinical effect. It is of the greatest value to have access to objective data which may be related to the symptomatology. Shunt angiography enables an objective evalua-

tion to be made of the anatomic outcome of the surgery, i.e. of the number of patent grafts postoperatively. By determination of the left ventricular ejection fraction it is possible to measure objectively the ventricular function before and after operation. This paper reports an attempt to relate the clinical picture after a by-pass operation to both shunt angiography and the left ventricular ejection fraction, and also to the degree of changes in the coronary arteries preoperatively. The clinical results are reported in detail elsewhere (5).

PATIENTS

This analysis was made on a consecutive series of 132 patients - 112 men and 20 women - who were operated on by the by-pass technique at the University Hospital in Uppsala during the years 1970 to 1976. They ranged in age from 36 to 68 years (mean 52.4). The indication for operation was stable disabling angina pectoris with a duration of at least six months, regardless of the heart size or the presence of hypertension or diabetes. At least three months should have elapsed since the last episode of myocardial infarction. The duration of angina pectoris in this series of patients was up to 10 years.

Preoperatively all patients underwent selective coronary arteriography and left ventricular angiocardiography. Determination of the ejection fraction by use of videodensitometry of the left ventricle was introduced as a routine procedure in 1974 (2).

The operation was performed with the aid of extracorporeal circulation, under slight general hypothermia ($30^{o}C$). Simultaneous with a median sternotomy a graft was taken from the great saphenous vein in the lower leg, in some cases bilaterally. After heparinisation, the superior and inferior venae cavae were cannulated and an arterial cannula was placed in the ascending aorta. The left ventricle was decompressed by insertion of a cannula via the left pulmonary vein. The peripheral anastomoses to the respective coronary arteries were performed first, using continuous 6-0 prolene sutures, during ventricular fibrillation and without clamping of the aorta. The body was then warmed and the heart defibrillated. After a side-biting clamp had been placed on the ascending aorta, the vein was anastomosed end-to-side to the aorta with 5-0 continuous prolene sutures. Postoperatively the patient spent one or two days in the intensive care unit, as a rule with tracheal intubation and artificial ventilation for the first 10 to 12 hours.

FOLLOW-UP

The patients were called for follow-up 1,2,3,4 and 5 years after operation. At these examinations the clinical condition was evaluated both by the grading of the New York Heart Association and with classification into five groups, according to the change in subjective symptoms, where group 1 implied freedom from symptoms, 2 much improvement, 3 some improvement, 4 no change and 5

deterioration. Postoperatively thoracic aortography was performed in 107 patients and left ventricular angiocardiography with videodensitometry to evaluate the ejection fraction in 77 patients. In 44 patients videodensitometry was carried out both before and after operation.

In order to diminish the risks at follow-up, as a rule only thoracic aortography (shunt angiography) was performed. Selective graft angiography was considered not necessary to determine graft patency or not. Further selective coronary arteriography was not usually performed unless this was indicated by the clinical condition or unless re-operation was planned. For left ventricular angiocardiography retrograde catheterization was used, and the examination was recorded on video tape, which was analysed with a videodensitometer(Philips, Stockholm) for determination of the ejection fraction.

For thoracic aortography the patient was placed in the horizontal supine position. Additional oblique projections were used when considered necessary. Simultaneous exposures were made in the frontal and lateral projections. An Arriflex camera was employed, with an exposure rate of 50 frames per second. A grey Ödman catheter with an outer diameter of 2.8 mm and an inner diameter of 1.8 mm was used in all cases. At the thoracic aortography 40 ml of Isopaque Coronar, 300 mgI/ml, was injected at a rate of 25 ml per second. At left ventricular angiocardiography for videodensitometry 20 ml of Isopaque Coronar, 300 mgI/ml, was injected at a rate of 15 ml per second. Two types of injection syringe were used: Medrad, Pittsburg, USA and Contrac, Contraves AG, Zürich, Switzerland. The laboratory equipment consisted of conventional bi-plane radiographic and image-amplifier apparatus.

The anatomic changes in the right coronary artery and the anterior interventricular and circumflex branches of the left coronary artery seen at preoperative coronary angiography were graded as follows: 0 = no change; 1 = a reduction in diameter of less than 50% at one or more places in the artery; 2 = a reduction in diameter of more than 50% at only one place in the artery; 3 = a reduction in diameter of more than 50% at two or more places in the artery; 4 = total occlusion.

The maximum possible score in any one patient was thus 12. By adding the three scores in each individual patient a rough idea of the degree of coronary arteriosclerosis was obtained.

RESULTS

Mortality

A total of 132 patients underwent a by-pass operation during the years 1970 to 1976, the frequency increasing with time (Fig. 1). Eleven patients (8 men and 3 women) died in the primary period (within one month after operation). The primary mortality remained constant during the years in question (Fig. 1). In the following four years a further 3 patients died, corresponding to an

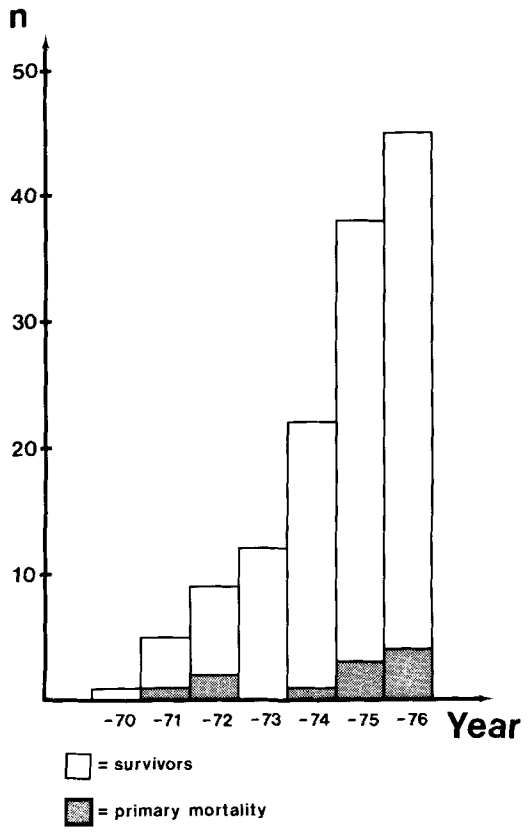

Fig.1. The number of by-pass operations performed each year during the period 1970 to 1976 at the University Hospital in Uppsala

annual mortality of 1.9%, 0%, 0% and 6%.

Subjective result

Of the remaining 121 patients, 114 have undergone at least one follow-up; thus 7 patients have not yet been followed up. At first examination one year, on an average, after operation, 99 of 114 patients (87%) considered themselves improved, 14 (12%) unchanged and one (1%) deteriorated. Preoperatively the majority were assigned to group IIIB of the New York Heart Association classification, whereas postoperatively there was a shift to groups II-III A. (See Table 1)

Table 1. Grouping of the patients according to the New York Heart Association classification, preoperatively and at follow-up one year, on an average, after operation.

	I	II	IIIA	IIIB	IV	
Preoperatively			11	102	1	114
Postoperatively	13	37	38	26		114

Roentgenological result

Seven of 114 patients refused thoracic aortography at the follow-up examination. In 90 of the other 107 patients (84%) this revealed that one or more

grafts were patent. In the remaining 17 (16%) all grafts were occluded. In the 3 patients who have hitherto been examined 5 years after the operation, all grafts were patent.

A significant ($p < 0.001$) correlation was found between the frequency of patent grafts and subjective improvement (Table 2).

Table 2. The absolute and relative number of patients with patent and occluded grafts in the groups with different subjective results of operation.

	Patent graft			Occluded graft		
	Number of patients		%	Number of patients		%
Symptom free	19			0		
Much improved	55	86/90	96	3	9/17	53
Some improvement	12			6		
Unchanged	4			7		
Deteriorated	0	4/90	4	1	8/17	47
	90		100	17		100

All 19 patients who were free from symptoms after operation (group 1) had at least one patent shunt. Of 58 patients who were much improved (group 2), 55 (95%) had at least one patent shunt, and in 3 patients all shunts were occluded. Of 18 patients who felt some improvement (group 3) at least one shunt was patent in 12 (67%) and all were occluded in the other 6. Eleven patients considered themselves unchanged (group 4); in 4 of these (36%) at least one shunt was patent, and in 7 (64%) all shunts were occluded. In one patient with subjective deterioration (group 5) the shunt was closed (Fig. 2).

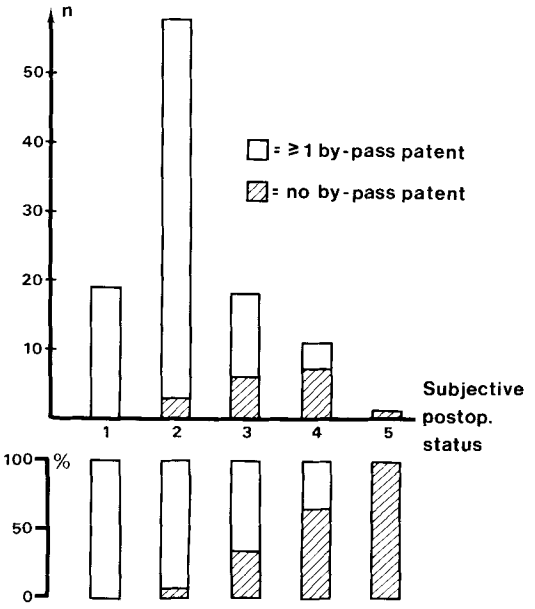

Fig.2. The subjective results of operation in 107 patients in relation to graft patency. The figures 1 to 5 refer to the groups defined in Table 1. The numbers of patent and occluded grafts are given as both absolute and relative values.

In 61 patients the left ventricular function (ejection fraction) was examined by videodensitometry before operation (Fig.3) and in 77 patients after operation (Fig.4). These histograms show that before operation the ejection

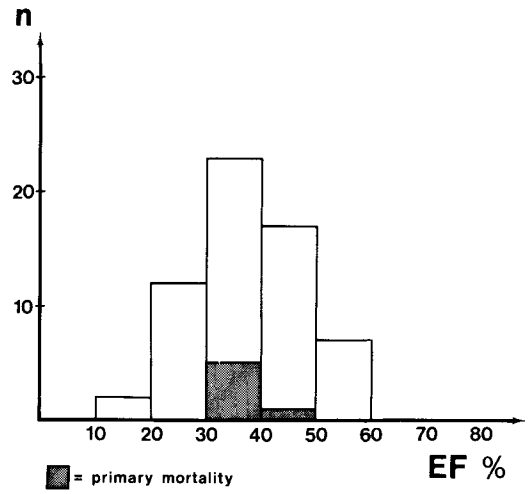

Fig. 3. The preoperative ejection fraction (EF) in 61 patients.

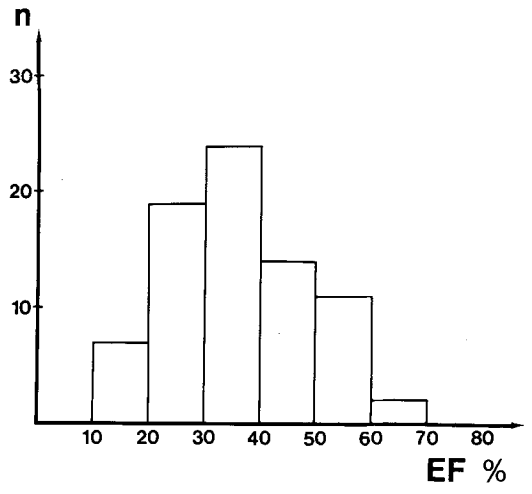

Fig. 4. The postoperative ejection fraction (EF) in 77 patients.

fraction varied between 0.10 and 0.60 (mean value 0.36). This fraction increased in 58% of the patients who had one or more shunt and in whom these were patent, the mean increase being 0.10. In the other 42% it decreased by an average of 0.17. The ejection fraction increased in 35% of the patients with both patent and occluded shunts, and in 25% of patients in whom all shunts were occluded. These results were obtained from 44 patients who were investigated pre- and postoperatively. No significant difference was found between patent and occluded grafts in relation to changes in the ejection fraction. The groups are too small, however, to permit a satisfactory statistical analysis. The ejection fraction was determined preoperatively in 6 of the 11 patients who died in connection with the operation, and the mean value was 0.34.

It was also determined preoperatively in 55 of the patients who survived, and here the mean value was 0.37.

In Table 3 the preoperative anatomic changes expressed by the scores at coronary angiography, are related to the subjective results at postoperative follow-up. Preoperative coronary angiograms were available for evaluation in 110 of 114 patients at the follow-up examination. Seventeen (63%) of 27 patients with relatively slight changes (score 0-4) and 33 (76%) of 49 with moderate changes (score 5-8) were found in groups 1-2, i.e. with complete relief from symptoms or much improvement. Further, 29 (85%) of 34 patients with marked arterial changes (score 9-12) were also free from symptoms or much improved after the operation. No statistically significant difference was found between these groups with different degrees of coronary arterial changes. This means that even the presence of advanced arterial changes does not prevent a good result of surgical therapy. Even when patients with retrograde filling of some arterial area were excluded, the degree of anatomic changes was still not correlated to the subjective result. With the same grading based on the findings at preoperative coronary angiography it was found that in 8 of the 11 patients who died in connection with the operation, who underwent preoperative coronary angiography, the mean score was 8.7. The corresponding figure for 110 of the 121 surviving patients was 6.8. However this difference was not significant.

Table 3. Preoperative arteriographic changes in the coronary arteries in 110 patients, in relation to the subjective result of operation (see p. 87 for definition of groups 1-5). Score 0-4 = slight arterial changes, 5-8 = moderate changes and 9-12 severe changes.

Degree of changes in the coronary arteries	Subjective result				
	1	2	3	4	5
0-4	9	8	4	5	1
5-8	10	23	11	5	0
9-12	3	26	4	1	0

DISCUSSION

According to reports in the literature the primary mortality in by-pass operations varies between 1-2% and 15% or more (6). The higher mortality figures are generally found in earlier series, and the lower ones after a certain "learning period" on the part of the respective surgical teams. In our series the primary mortality was about 8% and was essentially constant throughout the period of the investigation.

The indication for operation was always the same, namely disabling angina

pectoris. Recurrent myocardial infarction, cardiac enlargement, hypertension, diabetes, impaired ventricular function and previous surgery for angina pectoris were not regarded as contraindications to operation. Thus, of the 11 patients who died, 3 had previously undergone a Vineberg operation.

The selection of patients is probably a decisive factor (7). It is natural that far advanced coronary arteriosclerosis with myocardial impairment implies an increased operative risk. The idea of excluding this high-risk group from surgical theraphy might seem reasonable. This would mean, however, that many severely disabled patients in great need of palliation would be denied this possibility. Our results show a trend to greater improvement just in patients with advanced coronary artery disease, while at the same time supporting the assumption of an increased operative risk in this group. Evaluation on the basis of the ejection fraction would seem to be a conceivable way of selecting patients for surgery. Apart from some extremely low values indicating a clear surgical risk, however, the ejection fraction in this relatively small series of patients did not provide a safe index of the risk of operation. In our series there was no statistically significant difference in the preoperative ejection fraction between patients who died and those who survived.

In this investigation the by-pass operation was found to have a palliative effect on the angina pectoris, an effect which was correlated to the frequency of graft patency. The risk of operation increases in advanced coronary artery disease, but in successful cases the effect was very favourable. The question whether operation also implies causal therapy has not yet been definitely answered, except in the case of left main stem stenosis (6). No conclusions in this respect can be drawn from our results.

In about 60% of the patients who became free from pain, the ejection fraction was found to have increased at follow-up, compared with the preoperative value. This may be regarded as the most desirable and, in favourable cases, the most expected result. Freedom from pain and an increased functional capacity of the left ventricle may be regarded partly as separate factors, although they may have a common underlying cause.

Theoretically, a patent shunt should imply an increased blood flow to the myocardium. An improved blood flow may well explain alleviation of pain. Yet another effect of operation is conceivable, namely that further myocardial damage is prevented, in which case the ejection fraction, as an index of left ventricular function, would remain unchanged. With the same line of reasoning, an increased ejection fraction postoperatively would be an expression of an improved myocardial pumping capacity. Thus in certain circumstances the myocardial damage might be reversible. This could explain the higher postoperative ejection fraction in some of our patients. A possible reason for a decreased (or unchanged) ejection fraction after operation is that in spite of

an increased blood flow to the myocardium, the disease of the myocardium has advanced so far, that improvement of the myocardial function is not possible - this despite relief of the pain. The operation would thus be undertaken too late, when the myocardial damage is definitive or is increasing due to progression of the underlying disease.

Even insufficient myocardial protection during the operation might possibly explain a deterioration of myocardial function. These two conceivable cases of a reduced ejection fraction might be counteracted by earlier operation and a less traumatic surgical method, e.g. improved myocardial protection during the operative procedure.

The selection of patients for by-pass operations will be of decisive importance in the future. It would also be of value if the stage of development of the disease in the individual patient could be assessed (Fig. 5). Surgical

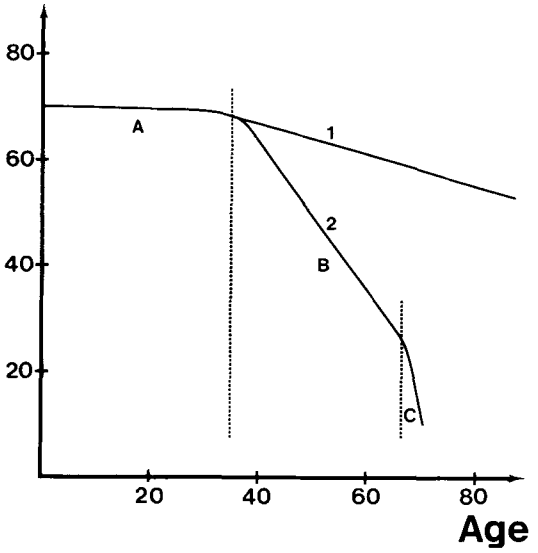

Fig. 5. A hypothetical curve showing the course of development of the ejection fraction (EF) in a normal person (1) and a patient with coronary artery disease (2). If operation is performed at phase C there will be no appreciable gain from the point of view of left ventricular function. On the other hand there will be a large risk of deterioration.

therapy should be undertaken before the myocardial damage becomes definitive and when it is still reversible. If an attempt were made to follow this principle consistently, the primary mortality would probably decrease, but on the other hand many high-risk patients with a possibility of considerable palliation would then be denied operation.

Further, coronary angiography of good quality is of great importance in selecting the correct location for a by-pass graft, to ensure that after the anastomosis the blood flow will be sufficient. Our series of patients is not large enough to give unequivocal results. It seems certain, however, that with increasing experience determination of the ejection fraction will be attributed greater significance in the future.

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