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MEDICAL GRAND ROUNDS

PARKLAND MEMORIAL HOSPITAL

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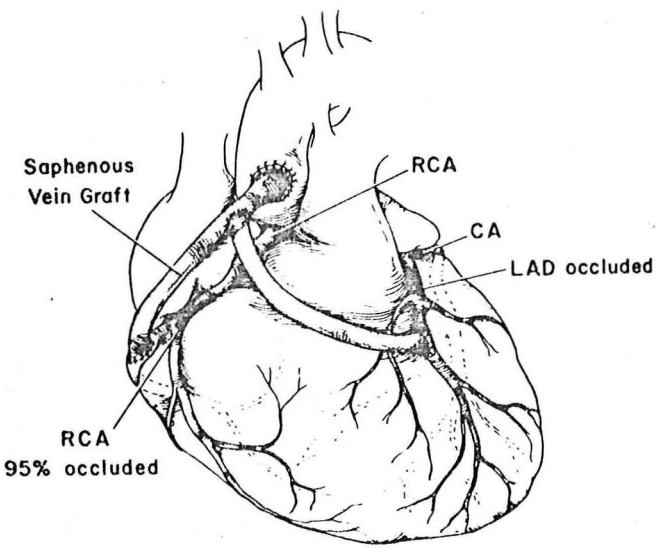
[Charles B. Mullins]

A CARDIOLOGIST'S VIEW OF CORONARY ARTERY SURGERY



"Surgery does the ideal thing -- it separates the patient from his disease. It puts the patient back to bed and the disease in a bottle."

Logan Clendening

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INTRODUCTION

Coronary artery disease afflicts 5% of the United States adult population; 3.1 million Americans between ages 18 and 79 definitely have coronary artery disease and another 2.4 million are suspected of having the disease. There are in excess of 1 million myocardial infarctions per year in our country with a mortality rate approaching 40%.

There is little wonder that a direct surgical attack on the coronary vessels themselves has been developed and is now reaching monumental proportions. Estimates now reveal in excess of 20,000 coronary operations have been accomplished in the past 12 months in this country alone.

The aortocoronary venous bypass graft has provided a surgical method of immediate revascularization of the ischemic myocardium - a surgical therapeutic triumph over coronary artery disease has been acclaimed by some enthusiasts. However, a note of skepticism must be entertained toward this type of enthusiastic approach and specific indications must be developed from accumulated data.

A review of the course of the disease process itself (coronary artery disease), the results and complications of the surgical procedures currently in use, and the comparison with medical management is warranted and will be attempted in this protocol.

A brief review of previous surgical attacks on coronary artery disease reveals a closet full of skeletons.

1) Sympathectomy
2) Thyroidectomy
3) Internal mammary artery ligation
4) Asbestos and talc pericarditis
5) Thromboendarterectomy
6) Patch grafts
7) Arterialization of the venous system
8) Internal mammary implantation (Vineberg)

These techniques have failed to produce either persistent clinical improvement or a decrease in infarction and mortality rates. Their evaluations were often years in evolving with many patients subjected to surgical procedures. The clinical study required to repudiate one of these procedures, internal mammary

ligation, was the sham operation (Dimond, *et al.*) in which the internal mammary arteries were exposed but not ligated and found to produce the same results as did division of the vessel (50% relief of angina). Serious evaluation of this new procedure for coronary artery disease must be forthcoming since revascularization of the myocardium is a necessity in coronary artery disease.

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PROGNOSIS OF ANGINA

Before the effectiveness of a surgical procedure can be evaluated, the uninterrupted course of the disease must first be evaluated. Therefore, the prognosis of angina pectoris, the prime indication for coronary artery surgery, must be reviewed.

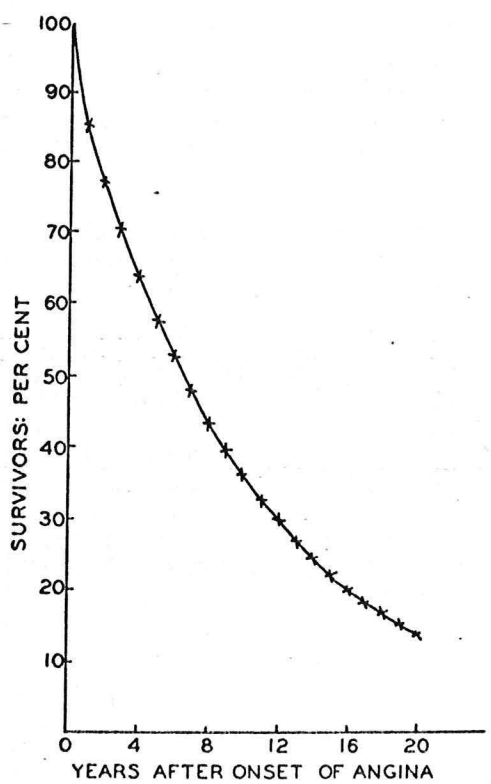
Angina pectoris is a spectrum of symptomatology, course, and prognosis depending upon the severity of the underlying coronary artery disease. This must be kept in mind when evaluating series of patients found in the literature. A review of the literature follows:

PROGNOSIS OF ANGINA PECTORIS

	Average Survival	
Older Literature	3-5 years	
White - 1931	8 years	
Eppinger & Levine - 1934	4.6 years	
Sigler - 1951	5.5 years	
Zoll - 1951	4 years	
Block - 1952	7 years	15% 1st yr; 9%/yr.
Richards - 1956	10 years	
Sigler - 1960	11 years	
Hurst, Harrison & Reeves - 1968	10 years	speculative

The longevity in this series superficially appears to increase in recent years. However, this is spurious since diagnosis and delivery of health care have improved in the past few years so that angina now is diagnosed earlier in its course than previously. The most reasonable statistical average for mortality is probably 15% the first year after onset of moderate to severe angina and a 9%/year mortality thereafter. This is probably not significantly different from the prognosis after recovering from an acute myocardial infarction. This mortality is 2-3 times the expected mortality in similar population groups without evidence of coronary artery disease.

A graphic summary of prognoses with angina is taken from Harrison and Reeves: *Ischemic Heart Disease*. Year Book Medical Publishers, 1968.



Kannel and Feinleib have recently evaluated the Framingham population for the risk of angina. In 303 patients with angina out of 5,127 population, 1 in 4 men with angina had a myocardial infarction or died from coronary artery disease within 5 years and 30% of those over age 55 died within 8 years. The risk for women was about one-half that for men.

There can be defined a group of patients with worse prognoses with angina pectoris than the average group of patients. These indicators of poor prognosis are important since these are the patients who most likely are candidates for coronary artery surgery. The average longevity in this group of patients is probably less than 5 years as compared with the milder syndromes of angina where mortality may be less than 4% per year.

Patients with angina pectoris associated with the following findings tend to have poor prognoses:

PAIN INDICATORS OF POOR PROGNOSIS

1) Minimal exertion
2) Frequent
3) Severe
4) Prolonged
5) Poorly responsive to NTG
6) Changing (New or ↑ Frequency)

CARDIAC FINDING INDICATORS OF POOR PROGNOSIS

1) Hypertension
2) Cardiac dilatation
3) Systolic bulge
4) Loud S_3 gallop
5) CHF
6) Ventricular conduction defect
7) PVC's or ventricular arrhythmias
8) Atrial fibrillation
9) Diabetes

Patients with these findings are not all necessarily candidates for surgical intervention since these findings (such as CHF) may also lead to high surgical risks. This will be developed later in the protocol.

Armed with this prognostic data in patients with angina, it becomes apparent that patients with mild anginal syndromes with no indicators of poor prognosis may not be candidates for coronary surgery until data proving an increase in longevity beyond 10 years has been accumulated. On the other hand, patients with a poor prognosis treated medically (*i.e.*, average survival <5 years) may be candidates for surgical intervention, provided the surgical mortality and 5 year longevity postoperative are no worse

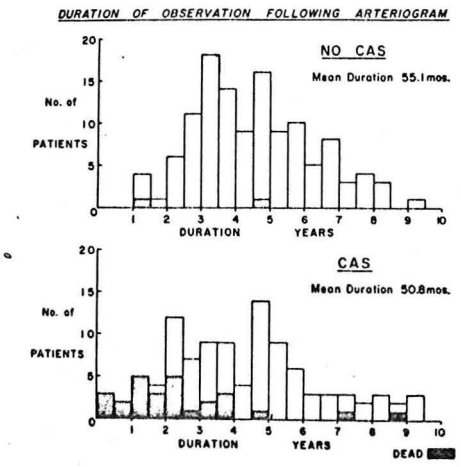
than the medically treated group. These patients would benefit by relief from angina and perhaps by an increased longevity with coronary surgery, *i.e.*, the quality of their lives would be improved, the quantity (longevity) hopefully would also be improved (unproved to date).

Also of importance in evaluating patients for surgical intervention is the prognosis of the patient with angina and 1, 2, or 3 vessel disease. Initially, venous bypass surgery for proximal isolated coronary artery lesions, especially in the right coronary artery, was an indication for operation since these lesions were technically easily bypassed. As surgical skill and techniques improved, bypass to distal coronary vessels as small as 1 mm lumenal diameter was accomplished with a high degree of success.

The longevity of patients with single coronary vessel paroxysmal obstruction has not been well documented until recently.

Friesinger, *et al.* reported a series of 224 patients referred to John Hopkins between 1960-1967 for evaluation of angina. All these patients had cardiac catheterizations with coronary angiography and were followed for a mean period of 53 months. Patients with heart disease other than coronary artery disease were not included. The clinical presentation, arteriographic findings and outcome were correlated.

The duration of observation is shown in the graph divided as to coronary artery disease present (CAS) or absent (NO CAS).



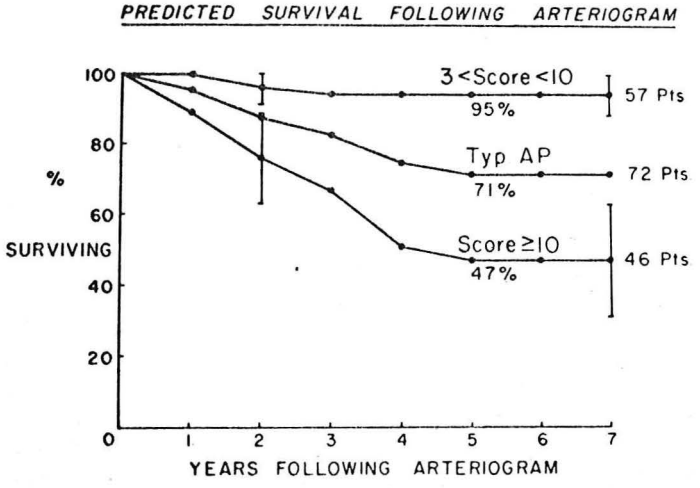
The predicted survival following arteriograms is shown on the following graph. Patients with mild CAD (3 <Score <10) are compared with patients with severe CAD (Score ≥10) (essentially 3 vessel disease). The patients with typical angina are also plotted. These findings suggest:

1) Anatomically mild coronary artery disease has a prognosis not significantly different from the general population (27 of the 57 patients had typical angina).

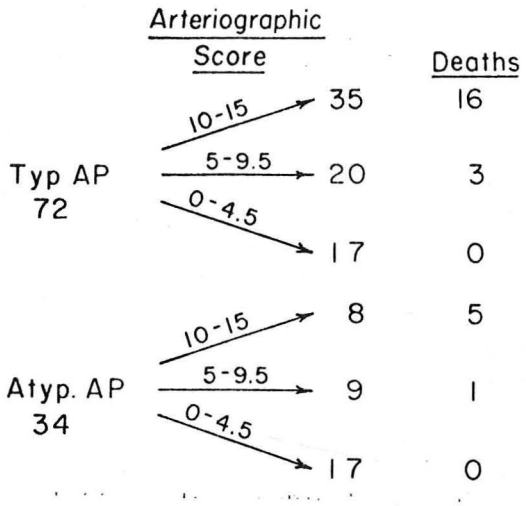
2) Severe anatomical disease has a poor prognosis - 50% survival at 4 years (35 of the 46 patients had typical angina).

3) A history of typical angina alone may be misleading since either severe or mild anatomical disease may be present. Mortality by typical history alone is about 5%/year.

Therefore, anatomical correlation with angina is important in evaluating prognosis.



Mortality also correlated well with the severity of anatomical disease but not as well with a typical history of angina. Again, scoring 10-15 = severe coronary disease; 5-9.5 = moderate coronary disease; and 0-4.5 = mild coronary disease.



An analysis of 32 of these patients with only single vessel disease is enlightening.

SINGLE VESSEL INVOLVEMENT

Number of patients	32
Mean age	39.2 years
Mean length of follow-up	54.0 months
Number of deaths	1 (auto accident)
Number who are complaint free	15 (46.9% = rate of disappearance)
Vessel involved	
LAD	24
RCA	6
LPC	2

These findings have been substantiated in a similar group of 246 patients studied at the Medical Center in Alabama.

It is evident that patients with a single vessel lesion have a good prognosis and probably are not candidates for coronary artery surgery at this stage of development.

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INDICATIONS FOR CORONARY ANGIOGRAPHY

Coronary angiography is the single most important diagnostic procedure for the surgical evaluation of patients with angina prior to surgery. The lesion must be identified anatomically since the bypass graft must be inserted in the coronary artery distal to the lesion for it to functionally increase distal coronary blood flow.

Anatomical lesions can be seen in the coronary arteries which reduce the lumen of the vessel by no more than 10%, however, flow studies have shown that physiological obstruction (*i.e.*, decreased blood flow) does not occur until the lumen is narrowed by at least 50%. Flow characteristics are also in-

fluenced by the length of the lesion, as well as the per cent of lumen narrowing. Generally, a coronary angiogram is considered positive if the lumen is narrowed by >60% and/or the coronary tree has loss of its usual branching (indicating branch obstruction).

General indications for coronary angiography are listed below. These are not necessarily indications for surgical intervention even if found to be positive.

INDICATIONS FOR CORONARY ANGIOGRAPHY

Diagnostic

1) Angina in young people
2) Atypical chest pain and normal resting and exercise EKG
3) Functional capacity and prognosis of mild angina
   a) Vocational rehabilitation
   b) Medicolegal
4) Atypical chest pain and nonspecific resting and exercise EKG
5) LBBB without angina or an MI
6) Recurrent arrhythmias of unknown etiology
7) CHF of unknown etiology
8) Asymptomatic patients with abnormal EKG

Surgical Evaluation

1) Incapacitating angina
2) Postcoronary surgery
3) Angina associated with valvular heart disease
4) Selective congenital heart disease
   a) Tetralogy
   b) Anomalous coronary artery
   c) Coronary A-V fistula

The coronary angiogram used to evaluate a patient for surgery provides the following necessary information:

1) Site and extent of atheromatous lesions
2) Quality, extent, and distribution of the distal coronary system
3) Presence and number of anastomosis

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EXPERIMENTAL AORTOCORONARY VEIN BYPASS GRAFT STUDIES

It is surprising how few animal studies have been reported in evaluating coronary artery surgery. Dedomenico, *et al.* have shown in 9 dogs that bypass grafts to the circumflex coronary artery have remained patent for 5 years. The grafts dilated but did not rupture and microscopic sections revealed fibromuscular hyperplasia to 3 1/2 times normal thickness.

Eckersdorf, *et al.* revascularized dogs after ligation of the LAD coronary artery by either the Vineberg technique of internal mammary implantation or direct anastomosis of the internal mammary to the distal LAD. They found the Vineberg procedure did not protect the myocardium from ischemia but the direct anastomosis did.

A significant investigation was carried out by Kakos, *et al.* in animals when they evaluated the hemodynamic relationships between an aortocoronary artery vein bypass graft and the

recipient coronary arterial circulation. They found (1) the vein bypass graft did not alter the flow in the distal coronary bed as long as the proximal coronary vessel was normal. (2) The graft supplied about 1/2 the distal flow. However, (3) in the presence of proximal coronary artery obstruction associated with a pressure gradient, the bypass graft supplied the distal bed but further reduced the flow through the proximal subtotally occluded segment which often resulted in stasis and total occlusion. This study certainly substantiates the clinical follow-up findings in patients of proximal coronary artery occlusions following bypass grafting.

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PERIPHERAL VEIN GRAFTS

Long-term follow-up data is now available on peripheral saphenous vein bypass grafts for femoropopliteal occlusive disease and is important in evaluating the expected course of coronary venous bypass grafts.

Darling, *et al.* have reported a 12-year follow-up on 295 peripheral vein grafts. There were 59 graft occlusions (20%), 42 patients died (14%) with patent grafts and 188 grafts were functioning at 6 months to 12 years (64%). The rate of occlusion is of importance. Approximately 87% of all grafts were functioning 6 months after surgery, 80% at 2 years, 73% at 5 years and 65% from 7-10 years. The early failure rate clearly approximates early failure in coronary bypass grafts.

Noon, *et al.* have reported the long-term patency rate in 95 distal tibial artery-vein bypass grafts. This vessel more closely approximates the size of the coronary vessels. The

patency rate was 74% initially, 65% at 6 months, 58% at 2 years, 51% at 3 years and 66% at 4 years. These results indicate a decrease in patency rate with decreased vessel size. In addition, delayed closure rates are significant and progressive.

DeWeese, *et al.* selected 103 consecutive peripheral venous bypass grafts and evaluated them at 5 years. They found an initial patency of 76% and a patency of 60% at 5 years. Most impressive in their follow-up was the mortality rates from associated disease, listed below:

MORTALITY RATE AS RELATED TO PREOPERATIVE STATUS (5 YEARS)

Age-Years	No.	Deaths	Mortality Rate (%)
50-59	37	12	32
60-69	30	10	33
70-79	24	19	79
80-89	6	4	67
Hypertension			
Present	30	16	53
Absent	73	33	45
Arteriosclerotic Heart Disease			
Present	35	25	71
Absent	68	24	35
Diabetes			
Present	25	20	80
Absent	78	29	37
Arteriosclerotic Heart Disease and Diabetes			
Present	14	14	100

It is apparent that peripheral vascular disease may be an indication of severe generalized vascular disease with a poor prognosis for longevity. Forty-eight per cent died within 5 years. Seventy-one per cent of these deaths were due to arteriosclerosis, *i.e.*, stroke or myocardial infarction. One

should weigh this evidence for shortened longevity in evaluating patients for coronary bypass grafts with associated peripheral vascular disease, especially in diabetics.

PERIPHERAL VEIN GRAFTS

		Patency Rate			
	Pts.	6 Mos.	2 Yrs.	4-5 Yrs.	7-10 Yrs.
Darling					
Femoropopliteal	295	87%	80%	73%	65%
Noon					
Distal Tibial	95	65%	58%	66%	-
DeWeese					
Femoropopliteal	103	76%	-	60%	-

These findings in long-term patency of peripheral vein grafts must be considered in the projection of patency rates in coronary vein grafts. Purely speculative, however, the coronary bypass grafts are subjected to shear and impulse forces several magnitudes above the peripheral vein grafts and thus vein graft fatigue might be expected to occur more rapidly. Intimal and medial fibrosis and hyperplasia may be a result of these forces. In addition, the distal coronary tree and the vessel size itself are smaller with less run off (decreased flow rates) when compared to the peripheral arterial systems resulting in an increased tendency to thrombose. Therefore, a decreased patency rate would be anticipated in the coronary system as compared to the peripheral vein grafts.

A significant and pertinent research study has been reported by Scott, *et al.* in which they studied the rate and extent of development of atheroma in peripheral vein grafts, arterial grafts, and dacron grafts placed in the arterial system. Dogs were made hypercholesterolemic after the grafts were in place and atheromatous deposits developed more extensively and rapidly in the venous grafts than in the other graft materials or in the dog's normal arterial system. Caution should be taken in extrapolating this to the clinical situation, however, if this does prove to be true in man, then the increased susceptibility of the vein grafts to atheromatous obstruction may rapidly negate any long-term revascularization effect. Perhaps consideration should be given to intensive lipid lowering therapy in patients following coronary venous bypass grafting.

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PATENCY RATE
CORONARY VENOUS BYPASS GRAFTS

Early patency rate of the venous bypass graft varies from 60-90% in reported series up to one year postsurgery. This compares very favorably with distal venous bypass grafts for femoral artery disease.

Early closure is related to:

1) Distal run off in the peripheral coronary bed. The less the distal flow the earlier the occlusion.

2) Flow rates in the vein graft. Early patency is directly related to flow. The higher the flow rates, the greater the patency rate. Flows have been recorded from 0-165 cc/minute. Early occlusion may be anticipated if flow rates are less than 40 cc/minute at time of surgery.

3) Proximal gradient: the greater the pressure drop (higher the gradient) across the proximal coronary artery lesion, the more likely the graft will remain patent, *i.e.*, the more flow will be carried by the vein graft. If very little proximal gradient is present, the flows carried by the coronary artery and vein graft are closely balanced and since vein graft flow would be decreased, thrombosis may occur.

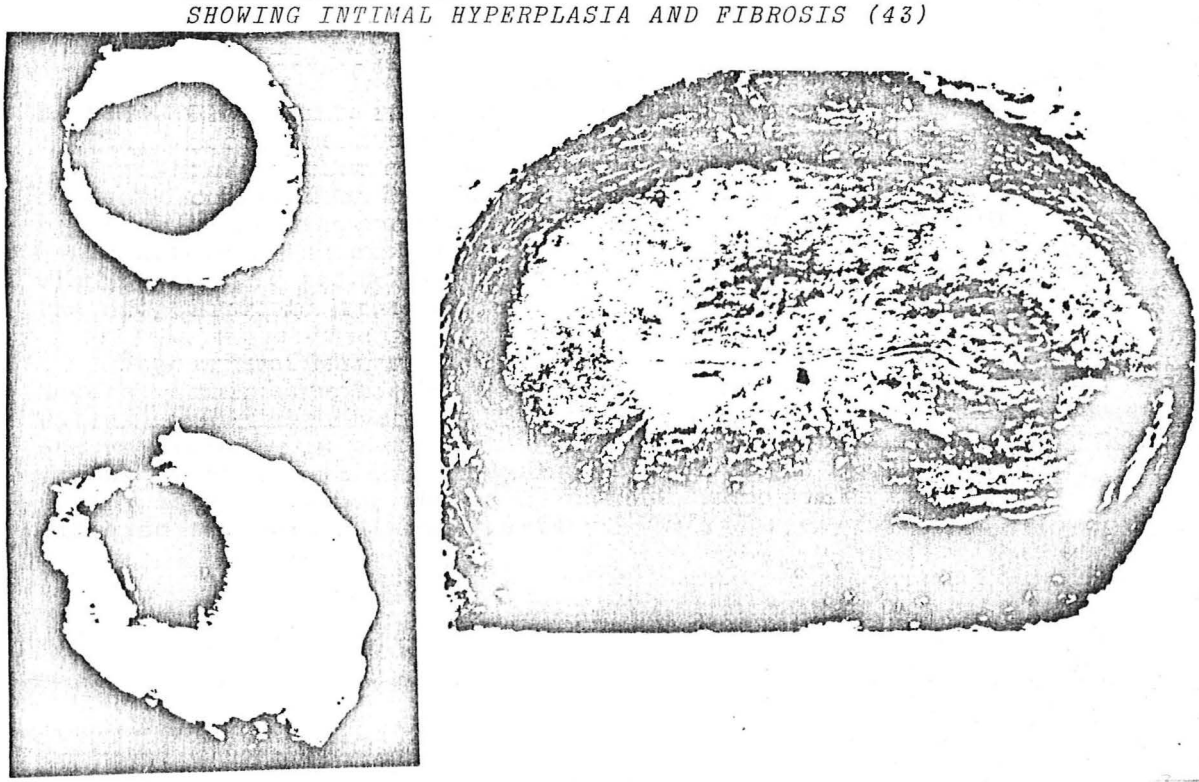
4) Condition of the myocardium: bypass into distal vessels which supply mostly scar tissue and poorly functioning myocardium tend to occlude due to low flow rates.

5) Vein size: the larger the vein used, the lower the relative flow rate due to the increased vein lumen/artery lumen ratio resulting in an increased tendency to thrombose.

Late patency rates are difficult to evaluate due to the few reports available. An estimate of late occlusion rates is probably at least 10% per year.

Late occlusion has been primarily attributed to intimal fibrous proliferative lesions in the vein segment as a response to arterial pressure. This same reaction has been reported in arteriovenous fistulae. Obstructive atherosclerosis in the artery beyond the anastomosis with the graft may favor the development of intimal lesions in the vein graft. Intimal hyperplasia has been shown to occur as rapidly as in a 3-week period in a graft in place for 3 1/2 months. The mechanical stress and shear forces (occurring during cardiac contraction), as well as the turbulence and pulsatile forces from the ejected blood, might be expected to rapidly accelerate the intimal hyperplasia in the venous segment.

PATHOLOGICAL SECTION OF CORONARY BYPASS GRAFTS SHOWING INTIMAL HYPERPLASIA AND FIBROSIS (43)



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ANOMALOUS LEFT CORONARY ARTERY; REPAIR BY VENOUS AUTOGRAFTS

Origin of the left coronary artery from the pulmonary trunk instead of the aorta is a rare lesion but may be the cause of angina, arrhythmias, and ischemic electrocardiograms in young patients. Definitive diagnosis can only be made by selective coronary angiography and the demonstration of a small left to right shunt via the coronary circulation from the right coronary artery with retrograde flow into the left coronary artery via anastomotic channels with flow into the pulmonary artery via the origin of the main left coronary artery.

Venous grafting provides definitive therapy for this lesion. Several cases have now been successfully corrected (NIH, Houston, Dallas). The saphenous vein is attached to the aorta and end-to-end anastomosis is made to the main left coronary artery or a venous bypass graft inserted from the aorta to the left coronary system after ligating the main left coronary artery at its origin from the main pulmonary artery. This surgery provides

definitive treatment for this anomaly.

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MORTALITY

Mortality with coronary surgery must be less than the mortality of the disease process treated medically. The techniques and skills of cardiovascular surgeons throughout the country have decreased operative mortality to a surprisingly low and very acceptable figure in selected patients.

The literature now has several thousand cases from which to draw experience. It is apparent that the initial operative mortality in the first 100 cases in any center is clearly different from the subsequent mortality as skill and experience is acquired, not only technical but also in patient selection. Mortality in the early series (first 100 ± cases) averages about 18%; in the next 200-300 cases the mortality drops to almost 10% and over 300 cases the mortality is further decreased to 2-5%. Amazingly, this operative mortality approaches the mortality in patients with coronary artery disease undergoing surgical procedures other than cardiac. These low mortality figures are compiled by and large from patients without predictably high risk factors as discussed in other sections of this protocol, such as congestive heart failure, left ventricular aneurysm, valve replacement, and associated diseases. It is also clear from the reports in the literature that the mortality increases with increasing severity of coronary artery disease, *i.e.*, the risk is somewhat higher in patients with 3 vessel disease than in single vessel disease. This may be reflected in reports as increased risk with increasing numbers of bypass procedures in the same patient, *i.e.*, Cleveland Clinic's last 100 uncomplicated cases:

"Mortality with right coronary artery bypass	4%
"Mortality with left coronary artery bypass	3.5%
"Mortality with multiple coronary artery bypass	5.7%"

On the other hand, if medically treated, the more coronary disease the greater the risk of death or of myocardial infarction.

The risk of myocardial revascularization in the elderly might be expected to increase over the risk in younger individuals and most importantly one must consider the patient's life expectancy and other disease processes which might lead to an early demise from other than coronary artery disease (*i.e.*, CVA). Enthusiasm has been voiced by some surgical groups, however, despite the initial enthusiasm, the mortality figures appear significantly prohibitive. Flemma from Dudley Johnson's group reported 47 patients over 65 who had vein bypass grafts. The initial mortality was 19% with 4% late deaths over a 3 year accumulative follow-up period. These findings appear to make the risk of coronary surgery in this age group (>65) prohibitive with perhaps a few exceptions.

The initial operative risk is certainly acceptable in patients without complications. The question now becomes, what is the mortality and morbidity (recurrent MI) in the survivors of the coronary bypass procedure when followed for several years? Unfortunately, long-term follow-ups are not available.

Dudley Johnson's group (McRaven, *et al.*) has evaluated their patients for a 2-year period from 1968-1970. Their first 309 patients had an initial survival rate of 86% (at 1 month) with a 3% one-half year mortality during the following 2 years. They further subdivided their patients as to severity of impairment of ventricular function. They found 1/2 year mortality rate of 1% in patients with normal ventricular contraction, and 4% in patients with diffuse left ventricular disease, and 15% with aneurysms. These results are encouraging surgical follow-ups, however, they appear not to differ from similar patients followed medically without the initial surgical mortality. Long-term survival rates must include the initial surgical mortality since the patients with worse disease have the highest mortality and those surviving may have less severe disease (survival of the fittest).

The long-term follow-up data at this time is too scanty to draw any conclusions regarding decreased morbidity and mortality following venous bypass grafts.

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PREINFARCTION ANGINA

"Preinfarction angina", acute myocardial infarction and cardiogenic shock due to myocardial infarction have been proposed as indications for coronary artery surgery, primarily because of the high mortality in these patients when treated medically.

Preinfarction angina, depending upon the definition, carries a 3 month mortality of 15-38%. If myocardial infarction can be prevented by the bypass procedure, then surgery would certainly be indicated. Several recent reports have indicated an anticipated mortality with surgery from 0-30%. However, patient selection and definition of "preinfarction angina" is so variable it becomes impossible to objectively evaluate these reports.

Segal, *et al.* have reported 17 patients with crescendo angina and ischemic EKG changes admitted to a coronary care unit. Bypass grafts were performed on all 17 with 2 deaths (11%) at the time of surgery and 3 others (20%) developed infarcts within 6 months. These results are probably no different from medically treated preinfarction angina, however, this needs careful investigation to be established

ACUTE MYOCARDIAL INFARCTION

Reports of surgical mortality in acute myocardial infarction varies from 0-100% with bypass grafting. At this time and until an increase in survival with coronary artery surgery above the 85% survival in CCU's with acute infarctions occurs,

I see *no indication* for coronary artery surgery in the face of an uncomplicated acute myocardial infarction.

CARDIOGENIC SHOCK

Cardiogenic shock secondary to an acute myocardial infarction heralds a high mortality (75-100%). A desperate attempt to provide increased myocardial perfusion in this setting has led to augmentation devices such as the intra-aortic balloon pump and coronary bypass surgery. Several reports indicate some degree of success with intra-aortic balloon support in patients with cardiogenic shock which is medically unmanageable. Blood pressure can be maintained at an acceptable level and left ventricular work reduced in many of these patients with aortic counterpulsation. If the patient is unable to maintain a blood pressure on the balloon assistance device or cannot be "weaned" off the balloon pump, then emergency coronary angiography and bypass is undertaken. Some of these patients have survived who otherwise would certainly have succumbed in cardiogenic shock.

Coronary artery surgery in the setting of medically intractable cardiogenic shock is a desperate but justified approach to management of myocardial infarction, especially if mechanical assistance devices such as intra-aortic balloon pumps are ineffective. Dunkman, *et al.* from the Massachusetts General Hospital have reported 39 patients treated with intra-aortic balloon assist for cardiogenic shock due to myocardial infarction. Thirteen of these patients were unable to survive off the balloon assist and were taken to catheterization and surgery for bypass grafting. Five of the 13 survived to be discharged which is a higher salvage rate than one might expect from medically managed cardiogenic shock.

Coronary artery bypass surgery may be indicated in patients with medical refractory cardiogenic shock due to coronary artery disease, since the mortality is so dismal and revascularization, if effective, may be the keystone to therapy.

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ARRHYTHMIAS

Recurrent ventricular tachycardia due to coronary artery disease unresponsive to medical management has been shown to be successfully treated with coronary artery surgery.

The following case report from our records exemplifies the successful surgical management of a patient.

Case Report - [redacted]

61 y/o male in good health until [redacted], 1969, when he suffered an acute myocardial infarction. His course was complicated by frequent PVC's, requiring treatment with procainamide and diphenylhydantoin, requiring both drugs at discharge after 6 weeks of hospitalization. On [redacted] 1970, he developed a syncopal episode and was readmitted to the coronary care unit with recurrent episodes of ventricular tachycardia (V.T.) The episodes occurred as frequently as 7 times per hour, requiring pacemaker overdrive cardioversion. Antiarrhythmic therapy was pushed to a maximum end point of toxicity without controlling the V.T. The drugs used were Dilantin, Pronestyl, Quinidine, Atropine, Propranolol, and Lidocaine. A cardiac catheterization was done on [redacted]/70 which revealed an LVEDP of 12 mm Hg, a normal size left ventricle with a small akinetic area at the left ventricular apex. Coronary angiography demonstrated a 75% stenosis of the distal right coronary and a 90% stenosis of the marginal branch of the left circumflex coronary artery.

Antiarrhythmic therapy in combination was again used for several more days without avail. On [redacted]70 the patient developed chest pain and an electrocardiogram suggestive of subendocardial ischemia. His V.T. became more frequent and more refractory to pacemaker overdrive cardioversion. On [redacted]/70, it was elected to submit him to operation for coronary revascularization since he was refractory to medical management.

A saphenous vein graft was placed from the ascending aorta to the distal right coronary artery and another from the ascending aorta to the obtuse marginal branch of the left circumflex artery. There was a fibrotic, small, thinned-out aneurysmal area on the diaphragmatic surface of the right ventricle which bulged during systole. This was plicated with horizontal mattress sutures and oversewn.

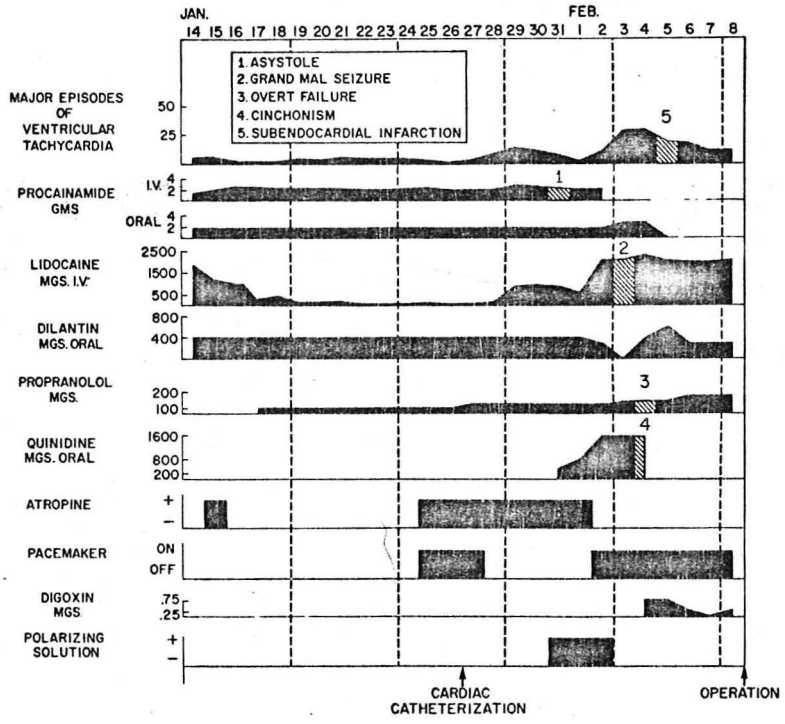
Postoperatively, the patient did well with only one unsustained episode of ventricular tachycardia 2 hours postoperatively. His only arrhythmia therafter was an occasional asymptomatic PVC.

A follow-up cardiac catheterization and coronary angiography was done on [redacted]/70. The right saphenous vein graft was patent and the right coronary system was unchanged except for retrograde fill through the vein graft. The left vein graft was not patent and the marginal branch of the left circumflex was occluded. LVEDP and the left ventriculogram was unchanged from preoperatively.

Graded exercise testing one year postsurgery revealed an almost normal exercise load at 600 KPM for 5 minutes with a

heart rate of 170; discontinued because of fatigue. The patient required no further medication.

DRUG THERAPY IN PATIENT [redacted] (79)



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CONGESTIVE HEART FAILURE

Congestive heart failure resulting from progressive myocardial ischemia has been suggested as an indication for coronary artery surgery. The potential for reversibility of chronic ischemia which has resulted in depression of myocardial function has prompted a trial of myocardial revascularization.

Two reports address themselves to this problem. Spencer, *et al.* reported 40 patients with moderate to severe congestive heart failure and coronary disease who underwent bypass grafting. The postoperative mortality was 37% over 10 months, most died within a few days of surgery. Gerald Austen's group reported 40 patients with 22% mortality, less than 70% had angina. Several of both groups of patients had combined procedures. These findings suggest that once congestive heart failure of moderate to severe magnitude has developed coronary surgery does very little to increase longevity. Improvement in cardiac function in the survivors was not sufficiently encouraging to warrant the surgical risks involved.

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VENTRICULAR FUNCTION

The direct evaluation of ventricular function pre- and postcoronary artery surgery is difficult since proper evaluation must include a pre- and postoperative catheterization with stress testing. The patient must be on the same medical regimen and should be near the same physiological state. Several attempts at evaluation have been reported but are less than satisfactory. These include evaluation of changes in Vmax and LVEDP to observations of increased contractions at time of surgery. Reports are usually in selected patients which immediately prejudice the evaluations. Stress testing is rarely included and

reference to pre- and postoperative medications is omitted. A summary of these studies follows:

1) LVEDP essentially remains the same. In patients with infarction or occluded grafts it may increase as might be expected. Rarely decreases.

2) Dp/dt - in selected cases usually improves slightly but probably not significantly. Controls of heart rate, drugs, stroke volume and catecholamine levels are not sufficient to make this measurement a valid index.

3) Ejection fraction - seems to increase slightly in patients with successful operations and in those patients with normal values preoperative. Those patients with depressed ejection fractions preoperatively usually decrease or remain the same after surgery.

4) Volume - end-diastolic volume in patients with successful operations usually remains the same; a few reports of decreased volume are reported. Those with unsuccessful operations (usually a result of infarctions and/or graft occlusion), the end-diastolic volume increases. End-systolic volumes occasionally decrease in patients with successful operations and increase in those with unsuccessful operations.

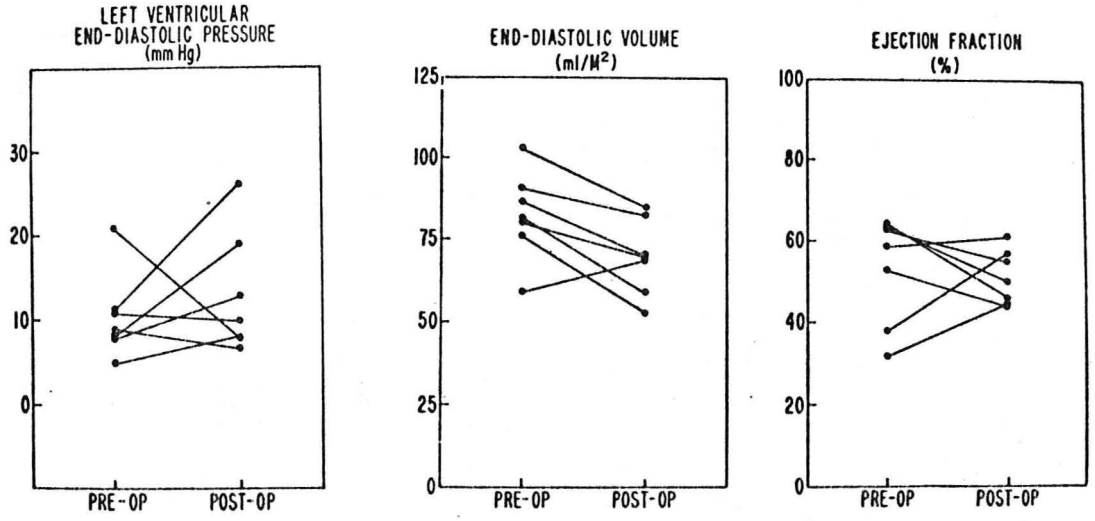
5) Asynergy (Saltiel, *et al.*; Chatterjee, *et al.*)
Akinesis - may partially improve after revascularization but never returns to normal. This implies that akinesis is associated with scarring (rather than ischemia) and would not be expected to improve.
Hypokinesis - often improves or returns to normal. Therefore, this must be related to myocardial ischemia and may be reversible by revascularization.

   Of interest was the finding that asynergy of the anterior wall was frequently reversible while it rarely changed in the inferior wall after bypass grafts to the appropriate coronary vessels.

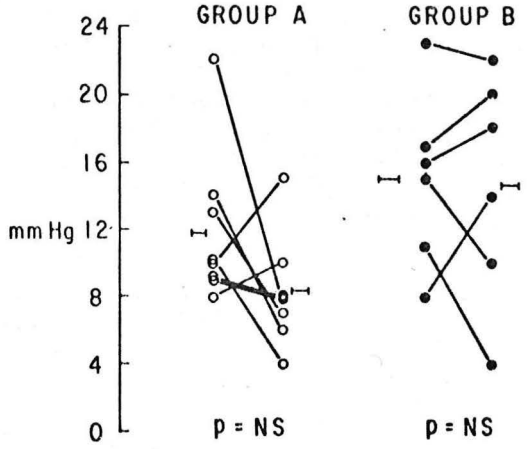
6) Vmax (Bolooki, *et al.*) - suggests an increase in Vmax in those patients with high values initially and no change in those with low values initially. Probably an inconclusive study.

In the reports of left ventricular function evaluation in *consecutive* (rather than selected) pre- and postoperative patients, no statistical change in parameters of ventricular function could be found.

Young, *et al.* have evaluated parameters of left ventricular function pre- and postop in 7 patients. These are shown below and probably show no statistically significant change.



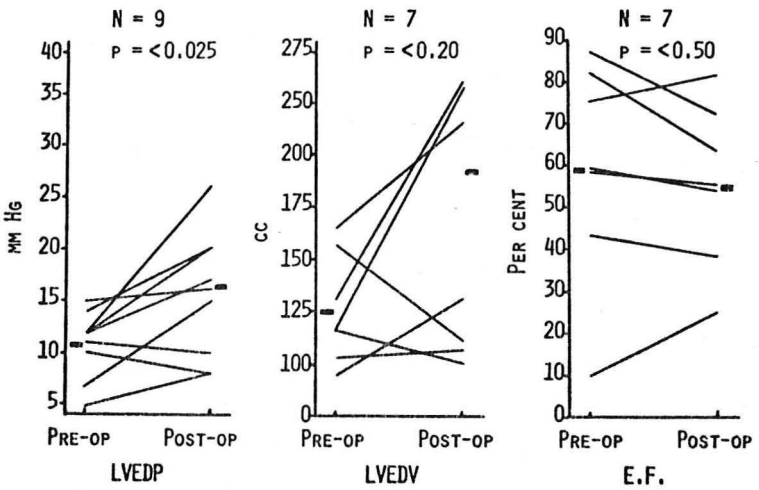
Reed, *et al.* evaluated 14 patients pre- and postoperative; 8 with anatomically good results (Group A) and 5 with anatomically poor results (Group B)(occluded grafts). The LVEDP and LVEDV were evaluated in both groups and found not to show statistically significant change.



LV End-Diastolic Pressure before and after Operation.

In summary, the reports evaluating left ventricular function pre- and postbypass grafting are of little value and frequently conflicting.

Ventricular function was evaluated in a consecutive series of 9 patients in this hospital at least 3 months post-coronary venous bypass graft. The changes in left ventricular end-diastolic pressure, LVEDP, volume LVEDV, and ejection fraction, E.F., are shown below.



These parameters of ventricular function in this small group of patients either did not change or showed slight deterioration in left ventricular function postoperative.

The major contribution in evaluation of ventricular function is in the selection of patients for bypass grafts. It is quite clear that poor ventricular function prior to surgery leads to a high (unacceptable) mortality rate and patients surviving the surgery rarely are significantly improved despite loss of angina. The majority of these patients are limited by left ventricular failure (low output - fatigue, etc., or congestion) postoperatively rather than angina at or near the same exercise levels.

Mortality increases to 20-56% in patients with ejection fraction less than 40-25%.

Therefore, patients with poor left ventricular function should not be candidates for revascularization at this time, with few exceptions.

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EXERCISE

Graded exercise studies have been used to evaluate pre- and postoperative improvement in work capacity. These studies have proven reliable in terms of anginal threshold since angina patients usually develop angina repeatedly at the same workload level.

A few exercise studies evaluated patients with coronary bypass grafts. It is evident from these reports that the majority of patients with good ventricular function preoperatively increase their exercise capacity following bypass surgery due to loss of angina or the development of angina at a higher workload. Many of these patients are almost symptom free in their usual life styles following surgery and are greatly benefited from the surgery.

However, a word of pessimism must be interjected. Most of the pre- and postoperative exercise reports have excluded patients with poor prognoses with venous bypass surgery and certainly the deaths are not evaluated postop! The patients with congestive heart failure, severe left ventricular dysfunction and/or associated abnormalities such as ventricular aneurysms, mitral regurgitation from papillary muscle dysfunction and valvular heart disease are excluded from exercise reports. These exclusions often result in glowing reports of improvement in exercise tolerance in patient series since they become weighted toward the most promising patients.

The limitation in maximum exercise testing preoperative is almost always (or should be) angina and/or electrocardiographic evidence of ischemia in patients who are candidates for venous bypass grafting. This limitation in maximum exercise tolerance is not comparable to the limitation (usually dysnpea) in patients with most valvular or primary myocardial disease, *i.e.*, ventricular function.

Patients evaluated post-bypass graft may be limited by ventricular function at their maximal exercise capacity rather than angina due to loss of angina with surgery. This may be at a higher or lower (poor surgical result) work capacity than before surgery. The loss of angina can result from one of two conditions after surgery - (a) increase blood flow to ischemic areas of the myocardium or (b) infarction of an ischemic area of the myocardium, *i.e.*, occlusion of a portion of the coronary system at the time of surgery or shortly thereafter.

It is a well-known finding in patients severely limited by angina that a myocardial infarction may result in loss of angina and improved work capacity after recovery. Thus, the interpretation of improved exercise tolerance postcoronary surgery is difficult since improvement may result from either revascularization or infarction. Improvement from angina may, at times, be at the expense of ventricular function and perhaps at the price of decreased longevity, *i.e.*, the quality of life may be improved but the quantity may be less. On the other hand, both quality and quantity may be improved, if revascularization has truly been accomplished.

A group of 50 patients has been studied in our exercise laboratory pre- and postbypass grafting (Bergman, *et al.*). The findings were:

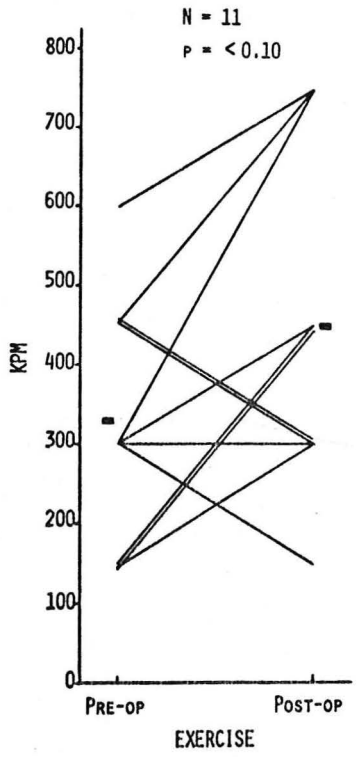
EXERCISE STUDIES

32/50 patients pre- and post-op exercise
6/50 operative deaths (12%)
4/44 late deaths (9%) - average follow-up time 13.5 months
15 weeks average exercise follow-up time
8 patients no post-op exercise

32 PATIENTS PRE- AND POST-OP

	Workload	Heart Rate	Heart Rate X S.B.P.
Before	440 KPM	130	228
After	522	144	276
Differential	+82 = 18%	+14	+47 = 21%
p	.02	.001	.001

Exercise changes in patients studied with both pre- and postoperative catheterization at PMH are shown below. The results are similar to the above group of patients.



These findings are similar to reports from other groups. In this series improvement in exercise tolerance is evident by the increased work capacity of about 20%. However, this improvement, as in other series, is not a great deal of increase in work capacity. Hopefully, by a year or more, post-op improvement may increase since the recovery from surgery and the effects of bed rest will be more complete.

The following case report exemplifies the problem of evaluating improvement in cardiac status with graded exercise testing pre- and post-op. This patient was limited at a low workload pre-op because of angina and was able to increase her workload post-op, now limited by ventricular function with evidence of more occlusive disease of her coronary system.

Case Report - [redacted]

This 44 y/o lady was a known diabetic since age 12. She suffered an acute anterior myocardial infarction in [redacted] of 1969 and an inferior myocardial infarction in [redacted] of 1969. She has had severe incapacitating angina since, requiring 10-20 nitroglycerin tablets daily. In addition, she had mild CHF compensated by digitalis.

A graded bicycle exercise test was performed in [redacted], 1970. She was limited by angina and ST changes at 300 KPM after 5 minutes and a heart rate of 124. An EKG showed Q waves in V_1 - V_5.

A cardiac catheterization was performed in [redacted], 1970, which revealed severe 3 vessel disease with complete obstruction of the right and left anterior descending coronary artery. A paradoxical aneurysm was present along the antero-lateral wall of the left ventricle and a dilated, poorly contractile LV was present with an ejection fraction less than 30% and a pressure of 130/5 mm Hg.

Surgery was performed with a venous bypass graft into the LAD and into the right coronary artery. The aneurysm was visualized but not resected since it was not large and was fibromuscular. She did well post-op but developed CHF a few weeks afterward controlled with drugs. She was angina free.

An exercise test was performed one year post-op on [redacted], 1971. The patient was limited by fatigue at 450 KPM at 3 minutes with a heart rate of 136. An electrocardiogram revealed Q waves in V_1 - V_4, unchanged from pre-op. A cardiac catheterization revealed an LV pressure of 150/8 mm Hg, an ejection fraction less than 30% and an occluded left vein graft. The right vein graft was patent with retrograde fill of the RCA. The RCA was totally obstructed distal to the site of the graft.

What is the improvement in exercise tolerance with medical therapy of angina when compared with improvement with coronary surgery? Serial graded maximal exercise studies were accomplished in our exercise laboratory in 8 angina patients with 4 beta blocking agents. The following improvement in exercise capacity resulted.

CHANGES IN WORKLOAD AT ANGINA

Beta Blocker	% Change ± S.E.	p Value
Placebo	+ 4 ± 3	N.S.
Propranolol	+30 ± 5	0.01
Sotalol	+23 ± 5	0.01
Practolol	+44 ±11	0.01
Oxprenolol	+30 ±15	N.S.

The level of improvement is at least equal to that resulting from the coronary surgery group. These are about comparable groups of patients but care in extrapolating the data to all angina patients is evident.

The comparison of symptomatic improvement with exercise probably has no relationship to longevity. Medical treatment of angina probably does not prolong life or prevent infarction. Coronary artery surgery may do both, however, no data is available to date regarding increased longevity with surgery and furthermore may be 10 years or more in the offing.

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97. Bergman, SA, Jr., Urschel, HC, Blomqvist, G: Pre- and postoperative exercise testing in patients undergoing direct myocardial revascularization. Circulation 43:II-141, 1971. (Abstract).
98. Dear, HD, Jones, WB, Harman, MA, Edwards, WS, Reeves, TJ: Direct myocardial revascularization: Postoperative assessment. Am. J. Cardiol. 29:92, 1972. (Abstract).
99. Bartel, AG, Behar, VS, Peter, RH, Kong,Y: Changes in treadmill exercise test after aortocoronary bypass surgery. Clin. Res. 20:24, 1972. (Abstract).
100. Russek, HI: Propranolol and isosorbide dinitrate synergism in angina pectoris. Am. J. Cardiol. 21:44, 1968.

PROXIMAL OCCLUSIONS

Several case reports confirm total occlusion of proximal coronary artery lesions after bypass grafts. The occlusions have been thought to occur from rapid progression of the coronary artery disease. However, as discussed in the previous experimental section, proximal lesions tend to occlude due to decreased flow through the obstructed area after bypass. Thus, it is no surprise that total occlusion of proximal coronary artery lesions result from bypass, and unfortunately have resulted in myocardial infarctions, despite patent grafts distally.

It is apparent that, in assessing hemodynamically the success of this operation, the coronary arterial tree as well as the graft should be re-examined.

The observation that functioning venous grafts do not prevent the occurrence of a myocardial infarction in the territory of the bypassed artery repudiates the premise upon which recommendation may be based for prophylactic coronary artery surgery in patients with few or no symptoms.

101. Aldridge, HE, Trimble, AS: Progression of proximal coronary artery lesions to total occlusion after aorta-coronary saphenous vein bypass grafting. J. Thor. Cardiovasc. Surg. 62:7, 1971.
102. Bousvaros, G, Chaudhry, MA, Phracha, AR: Progression of proximal coronary arterial lesions to total occlusion after vein graft surgery and its effects. Am. J. Cardiol. 29:255, 1972. (Abstract).

MYOCARDIAL INFARCTION

Acute myocardial infarction is probably the cause of operative death in coronary artery surgery and is also responsible for low perfusion, arrhythmias, hypotension and congestive heart failure in the early postoperative period. Nonfatal myocardial infarction occurs with a frequency of 9-20%. Resultant ventricular function may be impaired and angina may be lost due to the infarction.

Hultgren, *et al.* evaluated patients undergoing coronary artery surgery and found ECG evidence of infarction in 10% (Q waves)

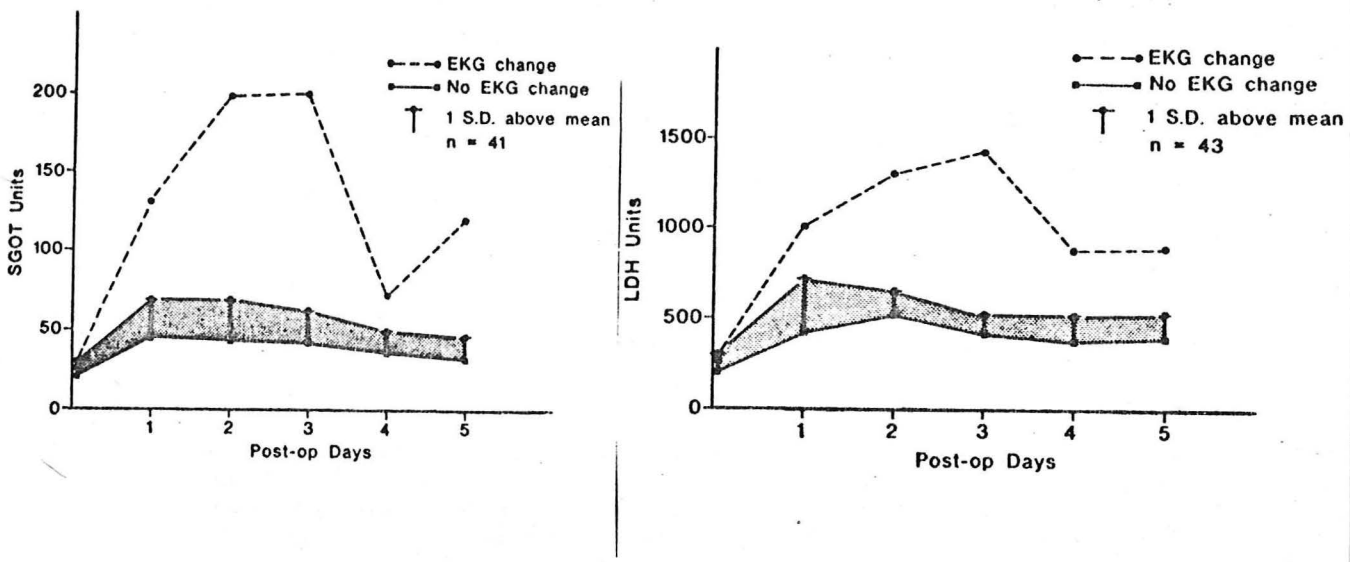
and ischemic injury in an additional 33%. Serum enzyme rises also occurred in 33-40% to levels suggesting myocardial necrosis.

Greenberg, *et al.*, Shirey, *et al.*, and Hultgren, *et al.* have correlated serum enzymes following open heart surgery (bypass) with ECG evidence of myocardial infarction.

Their separate studies agree that values of enzymes above those listed below correlated with myocardial infarction at time of open heart surgery.

ENZYME LEVELS SUGGESTING MI

SGOT	>	90 units
LDH	>	900 units
CPK	-	No value



From Hultgren, *et al.* showing enzyme rises with and without EKG changes of acute infarction.

These findings are not appreciably different from similar studies following the Vineberg operation. These studies suggest that postoperative "pericarditis" may often be myocardial damage. ECG findings of Q waves as a diagnostic criteria for myocardial infarction occur in approximately 10% of patients in serveral operative series with coronary bypass grafts; this conservative criteria for infarction certainly must underestimate the occurrence of infarction.

103. Hultgren, HN, Miyagawa, M, Buck, W, Angell, WW: Ischemic myocardial injury during coronary artery surgery. Am. Heart J. 82:624, 1971.
104. Greenberg, B, McCallister, B, Frye, R, Wallace, R; Serum glutamic oxaloacetic transaminase and electrocardiographic changes with coronary artery disease. Am. J. Cardiol. 26:135, 1970.
105. Shirey, E, Proudfit, W, Sones, F: Serume enzyme and electrocardiographic changes after coronary artery surgery. Dis. Chest 57:122, 1970.
106. Kouchoukos, NT, Doty, DB, Buettner, LE, Kirklin, JW: Treatment of postinfarction cardiac failure by myocardial excision and revascularization. Circulation 43:II-108, 1971. (Abstract).
107. Cohen, MV, Cohn, PF, Herman, MV, Gorlin, R: Diagnosis and prognosis of main left coronary artery (LCA) obstruction. Circulation 43:II-102, 1971. (Abstract).
108. Auer, JE, Johnson, WD, Flemma, RJ, Tector, AJ, Lepley, D: Direct coronary artery surgery for impending myocardial infarction. Circulation 43:II-102, 1971. (Abstract).

COMBINED PROCEDURE

Patients with valvular heart disease occasionally have combined coronary artery disease. The operative mortality in patients undergoing valve replacement with moderate to severe coronary artery disease often approaches 40% (NIH review). Therefore, with the development of bypass grafts it was reasonable to combine this operation with valve replacement in patients with coronary disease to perhaps decrease operative mortality and increase longevity. Resection of ventricular aneurysms have been combined with bypass grafting to the obstructed coronary arteries in an attempt to improve the left ventricular hemodynamics and to revascularize the ischemic areas of the myocardium. Reports are now available which discourage these combined operations. Most coronary bypass reviews exclude or separately analyze the patients with combined procedures.

Kouchoukos and Kirklin reported 8 patients undergoing combined operations with 4 deaths within the first 4 months after operation - a mortality of 50%. They concluded that combined procedures may have limited value. Flemma, Johnson, *et al.* also reported combined procedures in 13 patients with 7 deaths - a mortality of 54%. Our experience at Parkland Memorial Hospital further support these findings.

These results suggest that coronary surgery is generally not indicated in patients with moderate or severe left ventricular dysfunction undergoing valve replacement or aneurysmectomy.

109. Kouchoukos, NT, Kirklin, JW: Aorta to coronary artery bypass grafts combined with intracardiac procedures for acquired heart disease. Am. Surg. 37:700, 1971.
110. Flemma, RJ, Johnson, WD, Lepley, D, Auer, JE, Tector, AJ, Blitz, J: Simultaneous valve replacement and aorta-to-coronary saphenous vein bypass. Ann. Thor. Surg. 12:163, 1971.
111. Diethrich, EB: Technical considerations in combined valvular replacement and coronary artery bypass operations. Surg. Gyn. Obstet. 133:1015, 1971.

MEDICAL VERSUS SURGERY

Attempts to compare medical and surgical treatment of angina are found in the literature, all subject to shortcomings and with conflicting reports. Patient matching is almost impossible due to the variability of coronary artery disease, the associated complications and extreme variations in ventricular function. Most reports are retrospective while in prospective studies, the medical group tends to collect patients with worse ventricular function, with associated disease, and older age groups which contribute to increased mortality and morbidity.

It is now apparent that surgical mortality approaches the yearly mortality for patients with angina and is, therefore, an acceptable therapeutic tool, provided improvement in symptoms, signs, and/or longevity follow.

Without a doubt, venous bypass coronary artery surgery is an effective operation for angina since 85-90% of good risk patients are relieved of angina or significantly increase their angina threshold following surgery. Little evidence supports

a significant improvement in ventricular function. Improvement in longevity is still unknown, and it may be several years before significant changes can be effectively evaluated.

Random patient selection must be followed for several years before an answer will be forthcoming. Perhaps the Veterans Administration cooperative study will provide some insight into comparative findings between coronary bypass surgery and medical treatment.

112. Sehapayak, GK, Allison, WM, Pansegrau, DG, Grammer, JC, Kraus, WL: Results of aorta-coronary bypass graft surgery. Comparison with arterial implants and medical treatment. Am. J. Cardiol. 29:291, 1972.
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114. Russek, HI, Zohman, BL: Prognosis in severe angina pectoris with medical versus surgical therapy. Ann. Int. Med. 72:781, 1970. (Abstract).
115. Diethrich, EB, Liddicoat, JE, Kinard, SA, DeBakey, ME: An analysis of operated and nonoperated patients with documented coronary arterial disease. J. Thor. Cardiovasc. Surg. 57:115, 1969.

A diversity of opinion exists as to selectivity and indications for revascularization as can be seen from these notable quotes:

"The vein bypass procedures can and usually does improve myocardial performance. Coronary surgery should no longer be considered only in terms of relieving angina. We anticipate an increasing interest in coronary surgery for the preservation of myocardial function."

W. Dudley Johnson

"Coronary artery disease is, by nature, a chronic and progressive disorder subject to a great deal of individual difference and reaction. That coronary bypass surgery will alter this natural history, at this time, a hypothesis found wanting."

Henry Zimmerman

"At this time, there is no question that the operation in greater than 80% of carefully selected patients will restore blood flow to the compromised myocardium; increase myocardial metabolism and provide subjected relief from angina pain."

Richard Gorlin

"Surgical procedures, like drugs, are therapeutic agents. They are introduced to improve the health of man and not to injure him. Saphenous vein grafts for coronary arterial diseases have an operative mortality rate of about 10 per cent, a morbidity rate of about 25 per cent or more (pulmonary embolism, pericarditis, pneumonia, pleuritis, hemorrhage, myocardial infarction, cardiac causalgia, and many other complications and disturbances in health), associated with pain and suffering of 100 per cent, and a cost of $3,000 to $6,000 or more to the patient. The grafts do not cure the coronary arterial disease, about 25 per cent of the shunts close within 2 years, and the surgical procedure has never been subjected to any control studies such as sham operation or 'double-blind' evaluation.

"Imagine any capable cardiologist prescribing a pill that had never been subjected to double-blind control studies, that might kill 1 out of 10 patients, hurt 25 per cent, produce pain and suffering in 100 per cent, cost $3,000 to $6,000 to the patient, and never cure him! Not only would the cardiologist not prescribe such a pill, but also the F.D.A. would not allow the pill to reach the market and the public."

George E. Burch

"Current medical therapy has not been shown specifically to result in increased blood flow to the myocardium. Adequate revascularization operations do increase coronary blood flow. Whether either form of treatment prevents serious or fatal complications is not known, but surgical therapy seems more likely to do so. Until the factors responsible for the initiation and progression

of the disease are better understood, there will be no ideal treatment. The present question is not whether any patient should have operative treatment, but which patients are more safely treated in that manner and which are more suitable for drug therapy."

William L. Proudfit