Surgical Treatment of Coronary Artery Disease:
Medical Management and Evaluation of Results*

BERNARD L. BROFFMAN, M.D.**
Cleveland, Ohio

Surgical operation has proved to be safe and effective in providing the patient with coronary artery disease a more adequate distribution of coronary inflow to the myocardium. That operation can be carried out safely is attested to by the fact that in the last 100 consecutive patients operated to date by Dr. Claude Beck in Cleveland, mortality associated with operation has been zero. Long-term follow-up has already demonstrated increased longevity in operated patients. Furthermore, nine out of 10 patients evaluated six months to five years after operation have little or no pain and are economically productive.

This section of the symposium is based upon clinical observations on approximately 500 patients evaluated as candidates for the surgical treatment of coronary artery disease since January, 1951. To date, the Beck I operation has been performed on 225. Approximately 150 have been rejected for operation because of certain contraindications, usually extensive muscle damage and myocardial failure. Another 12 patients were considered acceptable for operation but died of their disease while awaiting hospitalization. One died suddenly 12 hours preoperatively. Approximately 110 others were considered acceptable for operation but have refused for various reasons or have delayed hospitalization; this latter group will eventually serve in a control series.

The clinical results associated with operation merely confirm the extensive laboratory evidence of benefit.1 Ideally, operation is an elective procedure to be applied as early as possible in the clinical course of coronary artery disease. Unfortunately, for many years surgical treatment was applied only to salvage patients in whom little could be achieved. Probably the greatest single deterrent to elective application of surgery has been the fear of high mortality expected of any surgical procedure performed on patients with severe coronary disease (however, with little consideration for the prohibitive mortality associated with standard medical therapy).

The demonstration of protection afforded by operation, with a remarkably low operative mortality, presents a challenge to the cardiologist. Unless definitive medical therapy can significantly modify the mounting disability and mortality resulting from coronary disease, the patient with this disease should be considered as a candidate for operation. Furthermore, skillful medical selection and supervision of patients in close cooperation with the surgeon is the sine qua non in achieving the excellent results that can be demonstrated.

*From the University Hospitals and Mount Sinai Hospital, Hexter Laboratory for Cardiovascular Research, Cleveland, Ohio.
**Director of Cardiovascular Research, Mount Sinai Hospital, Cleveland, Ohio.

Early in the development of the operation for coronary disease it was presumed that selection and evaluation of patients could be carried out best by a committee of cardiologists, each performing his own evaluation. Unfortunately, particularly in caring for the anxious patient with coronary disease, such a cold, "objective" approach tends only to increase his anxiety and rob him of the vital doctor-patient relationship. Ideally, a single competent cardiologist can offer both reassurance and careful evaluation.

**Indications for Operation and Classification of Patients:**

The one indication for operation is a positive diagnosis of coronary disease. The achievement of a low operative mortality now justifies the application of the operation to patients with "early" disease, before extensive myocardial damage has occurred. By the same token, the protection afforded by operation need not be withheld until the patient has had at least one myocardial infarction; early operation can reduce the 10-20 per cent mortality associated with the first episode of myocardial infarction. Operation may also be performed even after several episodes of infarction, but obviously little benefit can be achieved if the heart has begun to dilate.

Classification of patients with coronary artery disease is particularly difficult. Consideration must be given not only to the degree of myocardial degeneration but also to the progression of the occlusive process in the arteries. The following preoperative classification has been found useful:

Group 1. Patients with mild symptoms. Usually under 50 years of age. May have small infarct and/or mild angina.

Group 2. Moderately advanced disease. Moderate to severe angina. May have one or more infarcts. Normal heart size.

Group 3. (a) Salvage cases. Extensive muscle damage. May have large heart and congestive heart failure.

(b) Status anginosus.

(c) Certain contraindications.

The great majority of patients operated on are in Group 2. However, fortunately, the percentage in Group 1 is increasing. As a matter of fact, in members of families with a "bad" coronary history, operation should be considered at the earliest evidence of the disease.

**Contraindications:**

Acute myocardial infarction, or even suspicion of impending infarction, precludes operation for at least four to six months. In addition to the obvious dangers of operation during the acute stage, the delay allows for development of natural compensatory mechanisms. Operation is also hazardous in younger patients with rapidly progressive symptoms, particularly in those without previous myocardial infarction. These patients are prone to the development of areas of ischemia during or immediately after operation. These hearts tend to develop electrical instability with resultant ventricular fibrillation, so that an impending medical death becomes a surgical mortality.

Cardiac enlargement and evidence of congestive failure constitute a
relative contraindication to operation. However, in 20 per cent of the patients operated on in this series, the left ventricle was fluoroscopically enlarged. At least one-fourth of them had objective evidence of early congestive failure. Although it is too late for much benefit in such cases, the heart is remarkably stable and they tolerate operation quite well.

Severe hypertension, or any other associated disease which, per se, limits life expectancy, contraindicates operation. However, a moderate degree of blood pressure elevation was present in 25 per cent of those operated.

Age and Sex:

In this series of 225 patients operated, the age range was 27 to 72 with an average age of 48 years. Generally, those over the age of 65 carry an increased operative risk, but operation is not denied such a person if his tissue-age justifies it. Twenty in this series were over 60. In those under 40 years of age, the rapidly progressive disease usually present in this age group tends to make operation somewhat hazardous. However, operation was carried out in 30 under 40 years of age. Less than 10 per cent of the patients operated were women.

Symptoms and Duration:

In the present series, 75 per cent had suffered at least one clinically proved myocardial infarction. Two or more infarctions had occurred in 20 per cent. Angina pectoris, ranging in severity from mild to complete status anginosus, was present in 95 per cent of the patients operated.

The duration of symptoms, per se, of course gives no indication of the severity of the disease. The range in this series was four months to 13 years with an average of 2.9 years. In general, those with longer duration of symptoms appeared to tolerate operation better.

Preoperative Management:

The purpose of the preoperative study is to establish the diagnosis and to rule out contraindications to surgery. In persons with coronary artery disease, extensive diagnostic procedures do not constitute good medical management and actually may be dangerous. This fact was painfully demonstrated in the following two cases: Early in this series, in one with classical angina and an old posterior myocardial infarct, a gall bladder series was ordered "to rule out any other possible causes of chest pain." Soon after he ingested a large number of tablets for visualization of the gall bladder, he developed nausea and severe vomiting, followed by sudden death. In another, severe pain with evidence of an acute anterior myocardial infarction occurred suddenly as he was complaining bitterly during a barium enema. Death occurred 24 hours later. In both cases it is presumed that death was at least precipitated by unnecessary traumatic procedures.

Such usually superfluous procedures as the electrocardiographic exercise tolerance and anoxemia tests should be performed only when the diagnosis is in doubt. In a patient with a critically compensated coronary circulation, undue stress may produce catastrophic consequences. Obviously, in one
with electrocardiographic evidence of old infarction such tests are contraindicated. Furthermore, in one with typical symptoms, a negative test in no way alters the diagnosis.

The preoperative hospital stay should be as short as possible, usually less than five days. Exhausting tests are particularly contraindicated on the day before operation. Anxiety and apprehension appear to have a specific deleterious effect, and such patients have a greater operative risk, presumably associated with the lowered fibrillation threshold of the heart. Operation should be delayed until anxiety is allayed or at least reduced.

**Reduction of Thyroid Activity:**

In five in this series hypothyroidism had been previously induced by medical or surgical means. They had been seriously incapacitated and had not been significantly benefited by this treatment. Operation was considered particularly dangerous in such cases. However, they tolerated operation remarkably well; their hearts showed greater stability than euthyroid patients. Thyroid-epinephrine relationships are such that reduction in thyroid activity appears to play an important role in raising the fibrillation threshold of the heart. In accordance with these observations, in those with rapidly progressive disease (status anginosus) or severe anxiety, who are prohibitive risks for surgery, pre-treatment with anti-thyroid drugs appears to decrease significantly the operative risk.

Once it has been determined that there are no contraindications to operation, the procedure is carried out as soon as possible. Under no circumstance is operation performed unless the patient and spouse are in complete agreement and reasonably receptive. Furthermore, they must understand not only what operation can do, but also what it cannot do.

**Preoperative Digitalization:**

Prior to surgery all patients are completely digitalized. This is done even though there is no evidence of congestive failure. Contrary to certain theoretical concepts, digitalis definitely decreases myocardial irritability during operation. The various ventricular and supraventricular arrhythmias associated with cardiac surgery are significantly diminished by adequate digitalization. Specific beneficial inotropic and chronotropic effects are evident. In inadequately digitalized patients, annoying sinus tachycardias can be controlled by supplementary intravenous digitalis administration. The routine use of digitalis has been an important factor in achieving a remarkably low operative mortality.

At first, digitalis was used only sporadically and against the better judgment of most cardiologists. However, it soon became obvious that digitalis did not have the expected deleterious effect but seemed to maintain greater stability during operation. This observation was further strengthened during resuscitation experiments in the dog laboratory. Digitalized dogs could be resuscitated more readily and more frequently than those non-digitalized, and had a greater resistance to reversion to ventricular fibrillation.

Digitalization is continued until discharge from the hospital. However,
in those with cardiac enlargement and extensive damage, maintenance digitalis is recommended.

Management During Operation:

During operation, the surgeon, anesthesiologist, and cardiologist must observe close teamwork. Although the surgeon assumes the major responsibility, the cardiologist must be in command. Continuous electrocardiographic monitoring is essential. Various pharmacological agents and rest periods are judiciously applied as indicated. In most cases, however, operation proceeds from beginning to end without interruption. Of course it is desirable that operation be carried out as expeditiously as possible. However, there need never be undue haste. The duration of operation, within certain obvious limits, is in no way a consideration in the successful outcome. With good anesthetic management, oxygenation and maintenance of circulation during operation should be as adequate as that prior to induction of anesthesia.

A mechanical respirator (Rand-Wolfe) is always used. In refutation of theoretical objections to such a respirator, one need only point out the remarkably benign course of these patients. Oximetry and direct arterial saturation studies during operation have demonstrated the maintenance of a constant high level of arterial saturation throughout operation. Probably more important than the absolute level of arterial O₂ saturation, is the necessity for avoiding marked variations in oxygenation (such as have been demonstrated by oximetric studies during irregular intermittent manual compression of the bag). Sudden variations in myocardial oxygenation may produce dangerous oxygen differentials in the myocardium leading to ventricular fibrillation.

During cardiac manipulation various ectopic beats occur. Especially during epicardial abrasion, frequent ventricular premature beats and even runs of ventricular tachycardia appear, but subside immediately when abrasion ceases (Figure 1). Only rarely do these ectopic beats persist. There has been no instance of persistent ventricular tachycardia or fibrillation associated with this manipulation. So-called anti-fibrillatory drugs should not be used routinely. Procaine amide or quinidine should not be used empirically, in view of the myocardial depression produced. Only rarely is it necessary to use even small amounts of procaine amide for a particularly irritable heart.

The epicardial abrasion is frequently associated with ST segment deviations (Figure 2). Although there may be ST segment depression in the left arm lead and reciprocal ST elevation in the foot lead, these deviations are transient and return to the isoelectric line within a few days of operation. Rarely ST segment deviations followed by QRS changes suggestive of acute infarction appear soon after operation. Evaluation of such electrocardiographic findings is, of course, difficult. Serum transaminase levels have been of value in estimating the degree of myocardial necrosis associated with operation and in diagnosing myocardial infarction following operation. At the end of operation, all patients show a significant rise in serum transaminase. The peak is reached 48 hours postoperatively.
and generally is within normal limits by the fifth day. A sudden rise or undue elevation is indicative of acute myocardial infarction.

During operation, especially soon after induction of anesthesia, moderate bradycardia and hypotension may occur. Small doses of atropine sulfate (0.2 milligrams intravenously) specifically prevent a potentially dangerous slowing of the heart. Whenever moderate hypotension occurs, a rest period is observed and the lungs are well inflated. A small dose of atropine may then be tried. If hypotension persists, a gentle vasopressor (mephentermine, seven and a half to 15 milligrams intravenously) is given. Frequently this produces a sustained rise in pressure, although occasionally repeated doses are required. Rarely a more potent vasopressor drug (nor-epinephrine) is required. Generally, there is remarkably little fluctuation of blood pressure during the operation.

Examination of the heart at operation affords an excellent method for correlation with clinical impressions. The major coronary vessels are inspected and palpated with reference to tortuosity, pulsations, and patency. The heart size and character of pulsations are evaluated. Areas of scarring can be mapped out. By means of direct epicardial electrodes, accurate electrocardiographic survey of the myocardium has been carried out in many patients.

Operative Mortality:

Of the 225 patients operated since January, 1951, there have been 11 deaths associated with surgery (two during operation, nine in the early postoperative period), for a total mortality of less than five per cent. Care-

![Figure 1](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21290/)

**Figure 1:** Electrocardiographic observations during operation. Simultaneous unipolar left arm (L) and foot (F) leads show frequent ventricular premature beats associated with epicardial abrasion.—**Figure 2:** Electrocardiographic observations during operation. ST segment depression in left arm (L) with reciprocal elevation in foot lead (F) following abrasion of diaphragmatic surface of heart.
ful selection of patients and improvements in medical and surgical management have resulted in a progressive lowering of operative mortality, as evidenced by a series of 100 consecutive operations without a death. At least 30 of these 100 patients were salvage cases. However, in every instance symptoms had become fairly stable for a few months prior to operation. Recognition of the limitations of operation has prompted judicious delay in those seriously ill. Certainly, if a catastrophe is imminent, an ill-timed operation will only hasten it. A delay of a few months permits time for stabilization and greatly enhances toleration of operation and the achievement of a good result.

**Course of Patients After Operation:**

The immediate postoperative course is remarkably uneventful, even in those who appeared severely ill before. Rarely does the patient complain of pericarditis pain (even though the postoperative electrocardiogram most frequently shows such a configuration). Small left pleural effusion is frequent, but only rarely requires thoracentesis. Evidence of pericardial effusion is rare. In no case has long-term follow-up revealed evidence of deleter-

![Figure 3](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21290/)

**FIGURE 3:** Exercise tolerance test in a patient with severe angina prior to operation. The three standard limb leads and three chest leads show a normal control record (on the left). After only 15 ascents the patient had severe pain and developed marked electrocardiographic evidence of myocardial ischemia; ST-T deviations are present in all leads after exercise (on the right).
ious effect of the operation itself. Compression of the heart by a pericardial scar has not occurred.

In approximately 25 per cent there is almost immediate improvement in symptoms, so that a few days following operation they volunteer the observation that a given amount of exertion no longer causes pain. Generally, following discharge eight to 12 days after operation, they are encouraged to return to at least part-time work in four to eight weeks.

In the great majority there is progressive improvement over a course of one to six months after operation. Occasionally, one may show no improvement for a few months followed by a period of rapid and dramatic subsidence of symptoms.

Long-term follow-up of the first 100 alive at this time reveals a significant observation: At least 15 of them have had one or more severe “attacks” requiring hospitalization. However, in only three instances was there definite evidence of transmural myocardial infarction. Each one recovered and eventually returned to work with no worsening of symptoms. The other 12 have had one or more bouts of severe precordial pain (one has had five) associated with transient T-wave changes in the electrocardio-

FIGURE 4: Improvement in exercise tolerance test following operation. (Same patient as in Figure 3.) Nine months after operation the control record (on the left) is still normal. After 25 ascents there is no significant change: A negative test. This was consistent with a marked reduction in the patient’s angina.
gram. Usually, the pain subsided rapidly and they returned to work in one to four weeks.

In only 10 per cent did long-term follow-up reveal no improvement. However, in some of these there were such complications as severe narcotic addiction, psychoses, and cerebrovascular accident.

Remarkably enough, three who had evidence of early congestive heart failure prior to operation appeared to be much better compensated after operation. One of these, who had previously required weekly mercurial injections, has now gone eight months without injection.

Unfortunately, the very nature of coronary artery disease is such that so-called objective methods for evaluation of medical or surgical treatment are of little value. Reliance on the electrocardiogram or ballistocardiogram is unrealistic. Generally speaking, each one serves as his own control. No doubt, with a few more years of follow-up, a statistically significant evaluation will be forthcoming.

**Evaluation of Objective Studies:**

Serial electrocardiograms have been obtained in all patients before, during, and at regular intervals following surgery. Preoperative evidence of a myocardial infarct merely confirms the diagnosis. Postoperatively, invariably there are characteristic changes of pericarditis with eventual return to the preoperative pattern. Obviously, electrocardiographic evidence of myocardial regeneration is not to be expected. However, it is significant that in less than 20 per cent now living is there electrocardiographic evidence of further muscle destruction.

Early in this series, in an attempt to achieve a satisfactory objective method for evaluation, the standard exercise tolerance tests and the

*FIGURE 5: Ballistocardiographic improvement following operation. (D—displacement, V—velocity, A—acceleration.) The preoperative record (on the left) is grossly abnormal in a patient with moderate angina. One year after operation, obvious ballistocardiographic improvement is consistent with clinical improvement.*
anoxemia tests were applied even in those with evidence of previous myocardial infarction. However, the lack of correlation between these tests and the degree of coronary disease was discouraging. Furthermore, since the operative procedure results in a permanent pericarditis, electrical repolarization is interfered with, so that ST segment changes following exercise are difficult to evaluate. In many patients there has been excellent correlation between changes in the exercise tolerance tests and clinical improvement (Figures 3 and 4). However, in at least two with negative exercise tests prior to operation, subsequent tests have been positive despite marked clinical improvement.

The displacement, velocity, and acceleration ballistocardiogram (Arbeit Apparatus) has been grossly abnormal in more than 75 per cent tested prior to surgery. Generally, in the first week after surgery, a characteristic deterioration is demonstrated. However, in approximately 15 per cent studied, evident improvement over the preoperative tracing occurs by the end of the second week. In at least 50 per cent of the long term studies, there has been eventual improvement in the ballistocardiographic tracings (Figure 5). However, there is no obligate correlation with the patient's status.

Longevity:

Long-term follow-up has been carried out on the 137 consecutive cases discharged over a period of six months to five years ago (average: two years since operation). The expected mortality in such a group over this period would be 30 per cent or 41 dead. Actually 18 are known or assumed to be dead, a mortality of 13.1 per cent. Thus, even at this relatively early period, life expectancy can be shown to be increased by operation. Since operation does not prevent the occlusive process in the coronary arteries, a period of symptomatic improvement may be terminated by overwhelming occlusion and death. Such was the case in 50 per cent who died six months to five years after operation.

Present Status of Operated Patients:

Of the 100 consecutive patients who were alive and could be evaluated over a six month to five year follow-up period, 45 are completely free of heart pain. Another 45 claim that they have considerably less pain than before operation. Thus, 90 per cent have symptomatically excellent results.

By the same token, 42 are able to work with no limitations, while 48 are better able to work with some limitations. Thus 90 per cent are economically productive. (Prior to operation only 45 per cent had been able to work half-time or more).

SUMMARY AND CONCLUSIONS

The Beck operation for coronary artery disease is a safe and effective method for providing a more adequate distribution of arterial blood supply to the heart. Operation is indicated in patients with a positive diagnosis of coronary artery disease unless there is a specific contraindication. The operation should not be considered as merely a salvage procedure. Best results are obtained by operating early in the course of the disease.
In the last 100 patients operated, the mortality associated with operation has been zero. The over-all mortality for 225 operated since January, 1951 is less than five percent. Long-term follow-up reveals a significant increase in longevity for operated patients. Furthermore, 90 per cent were back at full time or part-time work with little or no limitations.

In view of the proved effectiveness of the Beck operation for coronary disease, the demonstration of a low operative mortality removes the operation from the category of salvage procedures and justifies its early application to a majority of persons with coronary disease.

RESUMEN Y CONCLUSIONES

La operación de Beck para la enfermedad coronaria es un método seguro y efectivo para proporcionar una mejor distribución sanguínea arterial al corazón. La operación está indicada en enfermos con el diagnóstico de enfermedad coronaria a menos que haya una contraindicación definida.

La operación no debe considerarse como intervención tan sólo de rescate. Los mejores resultados se obtienen operando tempranamente en el curso de la enfermedad.

En los últimos 100 enfermos operados la mortalidad dependiente de la operación, fue nula. La mortalidad global en 225 operados desde Enero de 1951 es menor de 5 por ciento. El seguimiento a largo plazo revela un aumento significativo en la sobrevida de los enfermos. Más aún, 90 por ciento regresaron a trabajar tiempo completo o parcial con pocas o ninguna limitaciones.

En vista de la efectividad demostrada de la operación de Beck para la enfermedad coronaria, la demostración de la baja mortalidad de la intervención la segrega de la categoría de procedimiento de último recurso y justifica la aplicación en la mayoría de las personas con afección coronaria.

RESUME

L'opération de Beck comme traitement de l'atteinte coronarienne est une méthode sûre et efficace, qui assure au cœur une distribution plus convenable de sang artériel. L'opération est indiquée quand on a porté nettement le diagnostic de maladie coronarienne, à moins qu'il n'y ait une contre-indication définie. L'opération ne devrait pas être considérée comme un simple sauvetage. Les meilleurs résultats sont obtenus en opérant dans un stade précoce de l'évolution de l'affection.

Chez les 100 derniers malades opérés, la mortalité opératoire a été nulle. La mortalité globale pour 225 opérés depuis janvier 1951 est moins de 5%. Des contrôles à longs intervalles de temps montrent une augmentation importante de la longévité pour les malades opérés. De plus, 90% ont repris leur travail à plein temps ou à temps partiel sans grande limitation de leur activité.

La démonstration de l'efficacité de l'opération de Beck dans la maladie coronarienne, la certitude d'une très faible mortalité opératoire, justifient que l'on ne classe pas cette intervention parmi les méthodes de simple
sauvetage, mais qu'on l'applique précocément à la plupart des individus souffrant de thrombose coronaire.

**ZUSAMMENFASSUNG UND SCHLUSSFOLGERUNGEN**


Im Hinblick auf die bewiesene Wirksamkeit der Beck'schen Operation bei Koronar-Erkrankungen hebt der Nachweis der geringen Operations-Sterblichkeit die Operation aus der Kategorie der Rettungsmassnahmen heraus und rechtfertigt ihren frühzeitigen Einsatz bei einer Mehrheit von Personen mit Koronar-Erkrankung.

**REFERENCES**

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