Triple and Double Arterial Implantation for Myocardial Revascularization*

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A technic was developed using a median sternotomy approach, by which triple or double arterial implantation in the myocardium might be carried out, using the right and left internal mammary arteries and the gastroepiploic artery. Triple or double arterial implantations were performed in 32 patients, two of whom died in the postoperative period. Over 90 per cent of the remaining patients have been improved. Arteriographic studies six to 12 months after operation have demonstrated patency of all three vessels following triple implantation. Operation of this type is thought to be particularly suitable for patients with multiple areas of myocardial ischemia. In addition, the surgical approach permits a second operation for patients who have previously undergone implantation of the left internal mammary artery. In two patients, the right internal mammary artery and gastroepiploic artery were implanted at a second operation.

Myocardial revascularization by implantation of the left internal mammary artery into the anterolateral part of the left ventricular myocardium has become widely accepted. However, the Vineberg operation, as usually performed, is limited, since ischemic areas may be lateral or posterior. In addition, use of a single artery may not suffice in patients with more than one zone of myocardial ischemia. Many patients with angina pectoris and coronary arteriosclerosis have narrowing of the anterior descending, the circumflex or the right coronary artery with ischemia of the anterior, lateral or posterior parts of the left ventricle. For these reasons, efforts have been made to devise operations which might revascularize the lateral or posterior part of the left ventricle.

Experiments in our laboratory demonstrated that an intercostal pedicle can provide a source of blood to the ischemic myocardium and can be implanted into any portion of the left ventricular myocardium. These studies were sufficiently encouraging to warrant clinical trial of the operation. Usually the sixth intercostal pedicle was implanted into the posterior part of the left ventricle and the left internal mammary artery was implanted into the anterior part of the left ventricle. However, this approach was not ideal because of the relatively small size of the intercostal artery.

Ferlic, Quattlebaum and Lillehei reported experimental studies and clinical application of "arterialized" autogenous vein grafts anastomosed to the thoracic aorta and implanted distally in the ventricular myocardium. Their results were encouraging, but other surgeons have not become enthusiastic about the procedure. Vineberg has described use of both the right and left internal mammary arteries mobilized through a left thoracic incision. Use of the right internal mammary artery also is certainly appealing since it is comparable in size and position to the left. However, mobilization of the right internal mammary artery through a left thoracic incision is tedious and awkward. Use of the splenic artery in dogs for revascularization of the diaphragmatic surface of the heart has been described by Gardner, Plybon, Glass and Warden.

To permit implantation of two or even three systemic arteries into the myocardium, we developed a technic using a median sternotomy through which both the right and left internal mammary arteries may be mobilized and implanted into the myocardium. In addition, the right gastroepiploic artery may be mobilized easily and implanted into the myocardium. Thus, two or three systemic arteries may be mobilized and implanted into the left ventricular myocardium through the same incision. Since development of this technic, the use of median sternotomy for mobilization and implantation of

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both right and left internal mammary arteries has
been reported also by Favaloro, Effer, Groves and
Sones. By upward and outward retraction of the sternal
edge, good visualization of the internal mammary
vessels is obtained. Each internal mammary artery
is mobilized from below upward so that arterial in-
flow is based upon the subclavian artery. The in-
ternal mammary vein, surrounding areolar tissue,
and portions of the sternocostalis muscle and fascia
are mobilized with the artery. The deep superior
epigastria artery and musculophrenic artery are the
terminal divisions of the internal mammary artery.
Frequently one may mobilize short portions of these
vessels and thus obtain a longer mammary pedicle.
The gastroepiploic artery is approximately the
same size as an internal mammary artery. Use of
this artery for myocardial revascularization was sug-
gested by Bailey, who has used it for this purpose.
The best method of mobilizing this vessel, as well
as the internal mammary arteries, was determined
dissection in cadavers. It was found that after
extending the median sternotomy inferiorly only 5
or 6 cm onto the linea alba and underlying perito-
neum, the greater curvature of the stomach and
gastroepiploic vessels bulge into the wound and are
only a few centimeters from the diaphragmatic sur-
fice of the left ventricle. The gastrocolic ligament
is divided along the greater curvature of the stom-
ach and the gastroepiploic artery and vein are di-
vided to the left and mobilized to the right from the
gastric wall. The pedicle includes surrounding fat
and areolar tissue. Arterial inflow is based upon the
gastrohepatic and hepatic arteries. Surrounding
fat and areolar tissue and the gastroepiploic vein
are stripped away from the distal portion of the ar-
tery which is to be implanted. The midpoint of the
diaphragm is divided posteriorly for a short dis-
tance to allow the gastroepiploic pedicle to arc
smoothly into the pericardial sac. The diaphragm is
subsequently closed loosely about the pedicle. The
gastroepiploic artery is implanted, freely bleeding,
in the left ventricular myocardium adjacent to the
posterior descending coronary artery. The technic
of implantation of this vessel is identical with that
used for implantation of the internal mammary ar-
teries. A tunnel 4–5 cm long is formed, either bluntly
or sharply, in the myocardium midway between the
epicardial and endocardial surfaces. The artery to
be implanted is incised transversely at two points,
or branches are transected at their origin, to allow
free bleeding. The artery is then drawn into the tun-
nel by a suture fixed to its end, and the tunnel is
closed sufficiently at each end to prevent bleeding
into the pericardial sac.

It is evident from our experience that, because of
its length, the gastroepiploic artery might easily be
implanted into the anterior or lateral part of the left
ventricular myocardium, although we have not had
occasion to do so.

The decision to implant one, two or three sys-
temic arteries into the myocardium is based largely
upon the locations of coronary artery narrowing
demonstrated by selective coronary arteriograms
before operation. Increasingly, we have been in-
clined to implant more than one artery. If decision
is made to implant three arteries, the right internal
mammary is placed anteriorly, close to the anterior
descending coronary, the left internal mammary is
placed laterally beneath a major branch of the cir-
cumflex coronary, and the gastroepiploic is placed
posteriorly adjacent to the posterior descending cor-

Figure 1. Triple arterial implantation for myo-

cardial revas-

cularization. The right internal mammary artery is
implanted anteriorly, the left internal mammary artery is
implanted laterally, and the gastroepiploic artery is implanted in the
posterior part of the left ventricular myocardium.

DIS. CHEST. VOL. 54, NO. 4, OCTOBER 1968
MYOCARDIAL REvascularization

beneath major branches of the coronary arteries are formed whenever possible. They have found a higher incidence of long-term patency of arteries implanted in this manner.

From February, 1966 through July, 1967, there were 22 patients who underwent double or triple arterial implantation (Table 1). Disabling angina pectoris was present in every patient prior to operation. These patients were from 23 to 59 years of age (average 46). Twenty were men and 12 were women. Fourteen had sustained myocardial infarction in the past. Selective coronary arteriography was performed prior to operation and provided definite evidence of coronary arterial occlusive disease in every patient.

Two patients died in the early period after operation. One of these patients, a man 56 years of age, had suffered three episodes of myocardial infarction in the past and had angina decubitus. At operation, multiple areas of myocardial fibrosis were present. Implantation of the left internal mammary artery and the sixth intercostal pedicle into the left ventricular myocardium was carried out. The patient did well until sudden development of hypotension, followed by cardiac arrest 22 hours after operation. Postmortem examination demonstrated recent thrombosis of the left circumflex coronary artery. The other patient, a man 57 years of age, had sustained myocardial infarction previously and had severe angina pectoris. Double arterial implantation using the left and right internal mammary arteries was carried out. Hypotension, followed by cardiac arrest, appeared suddenly six hours after operation. Postmortem examination demonstrated diffuse and severe arteriosclerotic occlusive disease of the right and left coronary arteries.

In the remaining patients the hospital course after operation was uncomplicated with the exception of two patients who required tracheostomy and assisted ventilation for 24 to 48 hours because of retained tracheobronchial secretions. Their subsequent course was entirely satisfactory.

Of the 30 surviving patients, seven have undergone operation within three months of the date of this report. All of these recent patients have improved clinically, but follow-up is too brief to assess results. Of the remaining 23 patients, nine have been completely relieved of angina pectoris. Eight patients are markedly improved with only occasional mild angina on exertion. Three are moderately improved with much less severe and much less frequent angina pectoris than before operation. Two patients have had questionable benefit from operation. One of these patients had become dependent upon frequent and large doses of narcotics prior to operation and this dependency has continued. The other patient has less angina, but is disabled by cardiac neurosis. There has been one late death, occurring three months after operation, due to acute myocardial infarction. It is not the purpose of this paper to present angiographic studies of implanted arteries but to describe the surgical approach which permits implantation of two or three systemic arteries into the myocardium, and our initial clinical experience with this operation. Only a few angiographic studies of implanted arteries have been performed in our patients since we prefer to wait at least one year from the time of operation.

An additional advantage of the surgical approach described in this paper is that it permits a second operation for myocardial revascularization in patients who have previously undergone implantation of the left internal mammary artery. Two of our patients have undergone two operations for myocardial revascularization.

The first patient, a woman 38 years of age, was first operated upon in May, 1966 through a left thoracic incision. The left internal mammary artery was implanted into the anterolateral part of the left ventricle and the sixth intercostal pedicle was implanted into the posterolateral part of the left ventricle. Moderate improvement occurred over a period of nine months after operation. At that time, however, episodes of angina pectoris became increasingly frequent and severe. The patient was hospitalized and received up to 1,000 mg of meperidine (Demerol) per day for relief of pain. In July of 1967 the second operation was performed, using a median sternotomy approach. The previously implanted left internal mammary artery was 4 mm in diameter and had a strong pulsation. No pulsation could be palpated in the intercostal pedicle, although surrounding adhesions to the pericardium and lung prevented adequate examination. The right internal mammary artery was mobilized and implanted beneath the lower portion of the anterior descending coronary artery and the gastroepiploic artery was implanted in the posterior part of the left ventricle adjacent to the posterior descending coronary artery.

<table>
<thead>
<tr>
<th>Arteries Implanted</th>
<th>No. Patients</th>
<th>Deaths</th>
</tr>
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<tbody>
<tr>
<td>Left and right mammary, and</td>
<td>8</td>
<td>0</td>
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<tr>
<td>gastroepiploic</td>
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<tr>
<td>Left and right mammary</td>
<td>9</td>
<td>1</td>
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<tr>
<td>Right mammary and gastroepiploic</td>
<td>8</td>
<td>0</td>
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<tr>
<td>Left mammary and sixth intercostal</td>
<td>7</td>
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OCTOBER 1968
Since operation in July, 1967, the patient has improved vastly, has only occasional mild angina on exertion, and no longer requires morphine (Demerol).

The second patient, a man 42 years of age, underwent implantation of the left internal mammary artery through a left thoracic incision. Within three months, he was completely relieved of angina pectoris and resumed work full time as a real estate salesman. Thirty months after operation, angina pectoris occurred and mild congestive heart failure appeared. A second operation was performed almost three years after the first. Through a median sternotomy, the right internal mammary artery and the gastroepiploic artery were mobilized and implanted into the anterior and posterior parts of the left ventricle. The left internal mammary artery which had been implanted into the anterolateral part of the left ventricle was strongly pulsatile throughout its length. Recovery from the second operation was prompt and he has been free of angina on restricted activity. Operation was too recent to assess the long-term result.

References

Mackenzie's Comments on Auricular Fibrillation

The most important of the continuous abnormal rhythms is that which is due to fibrillation of the auricles. The recognition of this condition and the symptoms associated with its presence is the most important discovery yet made in the domain of the functional pathology of the heart; and few physicians are aware of its significance. The symptoms directly due to auricular fibrillation and the symptoms of heart failure induced by this condition are so clear and definite that we have little difficulty in recognizing this condition as a distinct clinical entity. Its recognition is not of mere academic importance, but is of the greatest practical value; for when we recognize the various symptoms, they afford us grounds for a sure diagnosis, a safe prognosis, and for a rational line of therapy in a large proportion of cases of serious heart failure. The great frequency of its occurrence renders it imperative that all practitioners should become familiar with its symptomatology; for 60 to 70 per cent of all cases of serious heart failure met with in practice owe the failure directly to this condition, or have the failure aggravated by its presence. Some of the symptoms have been overlooked in the past, while the significance of others has not been appreciated. Moreover, the response of hearts affected with auricular fibrillation to remedies differs so much from the response of all other forms of heart action, normal and abnormal, that the recognition of its characteristics materially alters the views universally held as to the action of drugs upon the heart.