

## II—Surgical Treatment

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*British Medical Journal*, 1971, 1, 96–98

During recent years, which have seen an inordinate concentration of effort and publicity on heart transplantation—a procedure which can only be offered to a minority of patients—important advances in the surgical treatment of coronary artery disease, which have already benefited many hundreds of patients, have received little attention. The development of high quality coronary angiography has led to a better understanding of the coronary circulation and the pathological anatomy of these vessels. Morbid anatomical studies, haemodynamic investigations, and left ventriculography have allowed an assessment of the nature and frequency of the various conditions which are amenable to surgical treatment.

The aspects of surgical treatment to be discussed in this paper may be classified broadly as, firstly, the treatment of the sequelae of infarction (both early and late complications and power failure), and, secondly, treatment of coronary artery insufficiency. Before any form of surgical treatment is undertaken an accurate diagnosis is essential. This necessitates coronary angiography, left ventriculography, and in some cases right and left heart catheterization. These investigations may have to be carried out as emergency procedures in the acute phase, but, though this sounds alarming, in practice the procedures have been performed safely,<sup>32, 33</sup> if necessary with the aid of partial cardiopulmonary bypass.

### Early Complications

#### PERFORATION OF THE VENTRICULAR SEPTUM

This complication is responsible for 1–2% of all deaths after acute myocardial infarction. When the perforation is a large one (>1.5 cm/m<sup>2</sup>) it is likely to be rapidly fatal, and 80% of the patients die within eight weeks. If medical treatment fails to control the severe heart failure caused by the left-to-right shunt, early operation is essential. Ideally surgical treatment is delayed for five to six weeks to allow fibrosis of the margins of the defect to develop. The differential diagnosis from mitral incompetence due to papillary muscle dysfunction can be very difficult. Catheterization of the right side of the heart is therefore carried out as soon as possible when the diagnosis is suspected. The operation is performed using cardiopulmonary bypass. Especially in early cases, it may be necessary to close the perforation with a large patch of prosthetic material so as to avoid placing sutures in the friable muscle adjacent to the defect. The mortality is high in those patients who must be operated on within four weeks of the infarction,<sup>34–36</sup> but good results are obtained when medical treatment can tide the patient over the period of optimal delay.

#### PERFORATION OF THE FREE WALL OF THE LEFT VENTRICLE

Rupture of the heart occurs in 3–6% of patients with myocardial infarction, usually during the first week. Though death may occur almost immediately, the sequence of events

may be a sudden development of “shock,” with signs of cardiac tamponade, and the patient may survive for hours and even as long as a week. Slowing of the pre-existing rhythm, alternating with nodal rhythm, is probably diagnostic of acute tamponade in these cases.<sup>37</sup> Immediate operation with repair of the perforation has occasionally been successful.

#### ACUTE MITRAL REGURGITATION

Infarction of a papillary muscle, commonly the posterior one, of the mitral valve may result in papillary muscle dysfunction or rupture. Free mitral regurgitation results; the patient develops acute dyspnoea, and is found to have severe pulmonary oedema. With complete rupture the mortality is over 50% in the first 24 hours. Few of these patients are treatable because of their rapid deterioration, but mechanical circulatory assistance may improve the haemodynamic state for long enough to permit surgical treatment. If the condition is one of *dysfunction* of the papillary muscle, the patient develops a systolic murmur, which is initially ejection in type and later becomes pansystolic. The pulmonary oedema can be controlled by vigorous medical treatment, but usually the patient remains bedridden. Investigation shows that the heart is little enlarged, and on cardiac catheterization a late tall V wave of up to 50 mm Hg is seen in the indirect left atrial pressure tracing. This investigation—or left ventricular angiography, which shows the regurgitant stream and flail mitral cusp—is essential before proceeding to surgical treatment. Most surgeons have abandoned attempts to repair the mitral valve and prefer to replace it with a prosthesis. There are now many reports of complete recovery following this operation.<sup>38, 39</sup>

### Late Complications

#### LEFT VENTRICULAR ANEURYSM

Aneurysms follow myocardial infarction in about 10% of patients. In the majority they do not have any effect on the course of the disease, and rupture of the sac is rare. The indications for surgical treatment are progressive enlargement, persistent heart failure, or low cardiac output, embolism from clot within the sac, and intractable arrhythmia. Resection of the aneurysm requires cardiopulmonary bypass, and precautions must be taken to avoid embolism from dislodgement of the clot in the sac. The aneurysm is opened, the clot removed, and the fibrous wall excised, except for a fringe which is used to reinforce the suture line. The walls of the ventricle are then approximated with mattress sutures. The coronary circulation is not interrupted and the heart continues to beat throughout the operation, which is remarkably well tolerated. It might be expected that the reconstituted left ventricular cavity would provide an inadequate stroke volume, but the effects of the aneurysm lead to dilatation of the ventricle, so that one can be sure that if the patient has survived in spite of the presence of the dyskinetic area the capacity of the ventricular cavity will be sufficient. The operative mortality varies from 5–10% in different series<sup>40, 41</sup> and the improvement in the cardiac output in many cases is remarkable.

The prognosis in left ventricular aneurysm is not good because the development of an aneurysm indicates a large infarct and usually extensive arterial disease. In an attempt to

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improve the patient's prospects some surgeons now combine the operation with bypass grafts from the aorta to the coronary arteries beyond the obstruction<sup>42</sup> (see below). If a revascularization operation is projected, coronary arteriography must be carried out beforehand.

#### LEFT VENTRICULAR ASYNERGY

An asynergic area develops immediately in all cases of myocardial infarction. There may be lack of movement of the ventricular wall (akinesis) or paradoxical movement (dyskinesis).<sup>43</sup> Often function returns in a short time, but if the dysfunction persists it may be responsible for "cardiogenic shock" in the acute phase, and for chronic congestive cardiac failure or persistent low cardiac output later. The asynergic area also appears to be a focus of electrical irritability, and its removal can lead to stability of rhythm and easier ventricular defibrillation.<sup>44</sup>

This focal asynergic area can be identified by two-plane quantitative left ventriculography, but some newer techniques, such as ultrasonic echography,<sup>45</sup> radarkymography,<sup>46</sup> and electrical impedance cardiography,<sup>47</sup> permit the damaged area to be identified with minimal disturbance of the patient. The benefits of excision of the asynergic area have been shown experimentally on many occasions since the pioneering work of Gordon Murray in 1947,<sup>48</sup> and have been summarized elsewhere.<sup>49</sup> Recently a number of reports on the treatment of patients by excision of asynergic areas has appeared.<sup>50-53</sup> The patients were suffering from intractable heart failure or cardiogenic shock, and many had septal perforations, ventricular aneurysms or mitral regurgitation as well. For example, Schimert *et al.*<sup>51</sup> treated 21 patients with intractable heart failure and ventricular asynergy; 25-30% of the left ventricular mass was excised using cardiopulmonary bypass. There were three operative deaths and four more within six months. All except two of the survivors were relieved of their heart failure.

In the past patients with these features have been diagnosed as suffering from "muscle failure" and it has been assumed that the whole of the left ventricle is uniformly damaged. The results of surgical treatment have shown that it is well worth investigating myocardial function in detail in these patients. Excision of asynergic areas has also cured intractable arrhythmias following myocardial infarction in a few patients.

As with the treatment of left ventricular aneurysm, some surgeons have combined the excision of asynergic areas with procedures for myocardial revascularization.<sup>54</sup> Kay *et al.*,<sup>51</sup> finding the mortality unduly high in patients in whom cardiopulmonary bypass was used, developed the technique of excluding the inactive area of the ventricle by simply passing mattress sutures on a large needle through the ventricle from the posterior to the anterior wall. A similar operation was used to plicate asynergic areas of the posterior wall of the left ventricle, thus avoiding damage to the posterior papillary muscle. Thirteen out of 16 patients recovered.

#### Power Failure

This term is used to describe certain cases of cardiogenic shock. The mortality of this condition is still about 80%, in spite of the use of volume replacement, positive pressure ventilation, and hyperbaric oxygenation. Temporary improvement can be obtained in the majority by various techniques of mechanical circulatory assistance. The reasoning behind this treatment is that the changes in the infarct induce asynergy and ischaemia in the muscle around it, which may be reversible if coronary flow can be temporarily improved. Circulatory assistance also buys time for detailed investigation, and makes excision of the infarct possible in those patients who do not show permanent improvement. Emer-

gency resection of the infarct has now been carried out in several cases with complete recovery.<sup>50 55 56</sup> The mortality is of course high, but in this situation it is 100% without surgical treatment. There are still many unanswered questions about the place of infarctectomy. We do not know how much of the left ventricle can be excised in man. Estimates vary from 10-30%. The location of the infarct is of critical importance. It must be below the papillary muscles and must not involve the outflow tract of the left ventricle.

#### Myocardial Revascularization

During the past 30 years innumerable operations have been introduced for treating angina pectoris and have been accepted for a time with uncritical enthusiasm. Until recently there was no method of assessing these other than by the relief of pain. However, the variability of angina, placebo effects, and the results of subsequent infarction make any assessment based on this criterion valueless. Most of these operations have now been abandoned. There is little interest now in vein patch onlay grafts, thromboendarterectomy with loops or with carbon dioxide gas, or excision with end-to-end anastomosis.

Implantation of the internal mammary arteries into the myocardium introduced by Vineberg in 1946,<sup>57</sup> and its modifications,<sup>58</sup> have been widely used, but though it is claimed that angina is improved in over 90% of patients, there is still considerable controversy about the value of the procedure.<sup>59-61</sup> Few randomization studies have been carried out, and when they have the evidence of benefit in terms of reinfarction rates and late mortality has not been impressive.<sup>62 63</sup> There is suggestive evidence that the long-term prognosis is improved when three arteries are implanted into the myocardium.<sup>64</sup> In another series the incidence of subsequent myocardial infarction was found to be significantly less than in a medically treated group of patients,<sup>65</sup> but the overall long-term mortality was not less if the operative mortality was included. These comparisons have been made retrospectively with patients whose angina could be controlled by medical treatment. Even though coronary arteriograms showed a similar extent of disease, the groups cannot be accepted as identical for purposes of critical analysis. The operative mortality has varied between 5 and 14% in different series.

#### BYPASS GRAFTS

Following the developments in the widespread use of saphenous vein bypass grafts for relieving obstruction in the limb arteries, and technical advances in the anastomosis of small vessels, attention turned to applying these methods to the coronary arteries. In recent years impressive results have been obtained. The vein grafts are anastomosed to the ascending aorta proximally, and to small branches of the coronary arteries distally. An anastomosis can be made to any vessel greater than 2 mm in diameter, and in almost all cases of coronary artery disease the branches at this level are found to be free of atheroma. Cardiopulmonary bypass is used during the procedure, and two or three vein grafts are often inserted into different branches at the same operation. The operative mortality is remarkably low. Thus Favaloro reports a mortality of under 4% in 1,100 patients,<sup>66 67</sup> and Lepley and Johnson figures of from 7% for those with good left ventricular function to 15% overall.<sup>68 69</sup> The late patency rate is about 85%, though the period of follow-up is still relatively short. Many of these patients have had left ventricular failure, and there has often been an improvement in myocardial contraction as soon as the blood supply is restored. The relief of angina is immediate, and often a decrease in heart size has been seen in the early postoperative period. In some cases the procedure has been combined with valve replacement and

excision of left ventricular aneurysms or asynergic areas.

It is not possible at present to assess the results of this operation because the follow-up period is too short. It is known that when vein grafts are anastomosed to peripheral limb arteries with a diameter of 2 mm half of them become occluded within one to two years, and therefore some reservation is necessary about the long-term prognosis. Hence at present the indications for the operation must be considered carefully. The procedure should certainly be considered in all patients who are undergoing an operation to deal with some mechanical complication of infarction. Otherwise, it should probably be confined to patients with angina that does not respond to medical treatment. Coronary arteriography will have shown severe obstruction or total occlusion of one or more arteries with patent distal arteries beyond the obstruction. The indication for operation will be stronger if the

patient also has left ventricular failure, but diffuse ventricular dilatation in a patient without angina is a contraindication. The operation should not be carried out within three months of an episode of infarction.

If the long-term results show that life is prolonged and the incidence of subsequent infarction reduced, there will be a strong case for advising this operation in many patients with coronary artery disease even if their angina can be controlled, for medical treatment cannot at present offer any protection against subsequent infarction.

Finally we must consider the possibility of surgical treatment for acute coronary insufficiency. It is questionable whether medical treatment influences the outcome, and myocardial infarction often follows. A few patients have been treated by an emergency vein bypass operation,<sup>65</sup> and the results so far have been encouraging.

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