Controlled reperfusion in the surgical treatment of acute myocardial infarction

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History and present overview

The therapeutic approach to acute myocardial infarction (AMI) has undergone some substantial changes due to the cultural and technological advances in the medical and surgical fields[1]. Up to the 1970s, and with the aim of reducing post-AMI mortality, various methods of protecting the ischemic myocardium were attempted that mainly concerned the reduction of oxygen consumption, the restoration of oxygen supply, the surgical treatment of mechanical complications, and the use of metabolic helpers for myocardial fibers (hyaluronidase, polarizing solutions, carnitine, etc.).

Clinical results led to research being directed towards the concept of early recanalization or revascularization as the only procedure capable of arresting the ischemic process by limiting the extension of the necrotic area as much as possible.

Several therapeutic approaches have been put forward as alternatives to each other with indications which have been discussed in recent years[2]: thrombolysis, coronary angioplasty, and surgical revascularization[3].

Potential advantages of surgical reperfusion, emerged in past experiences[3-5] at the end of the 1970s, were reduced mortality, complete revascularization also of the coronary branches uninvolved in myocardial necrosis, improved ventricular function and the complete resolution of the acute ischemic event and of its effects on the coronary disease during only one hospitalization period.

The data relating to the study demonstrated that the speed of reperfusion was fundamental in sparing the myocardium and reducing long-term mortality, preventing the depression of contractile function. The efficacy of surgical revascularization has also been demonstrated in patients with AMI complicated by shock, although the reported mortality rate is never less than 20%[3,4,6].

At the end of the 1980s, the group of Buckberg[7] showed that treatment of the ischemic myocardium able to restore pre-ischemic conditions or limit reperfusion damage should include:

reduction in cardiac work and decompression of the left ventricle by means of extracorporeal circulation;

myocardial protection achieved by means of blood cardioplegia;

controlled reperfusion using a substrate-enriched blood cardioplegic solution;

protection of ischemic territories surrounding or distant from the infarcted area.

Experimental data have demonstrated the impossibility of using reperfusion with normal blood to restore the normal contractile function of an acutely ischemic muscle caused by a coronary occlusion lasting more than 2 hours[8]. On the other hand, it has been experimentally demonstrated that prolonged ischemia lasting even more than 6 hours does not provoke irreversible changes in the structure and function of the mitochondria and that the early recovery of contractility is possible if the conditions of reperfusion and the composition of the reperfusate are controlled[7].

Surgery is currently the only means of applying controlled reperfusion, and clinical data[6,9] have confirmed the experimental data showing the superiority of controlled reperfusion methods, above all in subgroups of high risk patients.

In spite of the Buckberg studies, the surgical treatment of AMI has always been limited to the treatment of the complications of other methods of acute revascularization.

Nevertheless, a study of revascularization methods[6] has reported that the use of coronary angioplasty led to the recovery of segmentary contractility in about 50% of cases and, in these, the post-treatment values were no more than 40% of normal values; the recovery of segmentary contractility (moderate residual hypokinesis) after surgical revascularization (controlled reperfusion) was achieved in 92 and 87% respectively of the patients treated at a mean of 3.1 and 6.3 hours after the onset of symptoms[2]. This fact reflects also in postoperative NYHA functional class[5].

The Buckberg protocol of controlled reperfusion follows these steps:

normothermic hyperkaliemic substrate-enhanced blood cardioplegia induction (retrograde or mixed): to regenerate metabolic conditions before aortic cross-clamping;

cold (4 C) hyperkaliemic cardioplegia (retrograde or mixed): to keep electromechanical silence;

cold (4 C) hyperkaliemic cardioplegia every 20 min, with perfusion of venous grafts: to maintain a regional homogeneity of reperfusion;

normothermic substrate-enhanced blood cardioplegia reperfusion, also in venous grafts: hyperkaliemic (3 min) for maintenance of electromechanical silence, mormokaliemic (17 min) in the left anterior descending coronary artery graft.

The positive effects of extracorporeal circulation in all of the situations involving severe hemodynamic impairment are reduction in the heart work and restoration of adequate peripheral perfusion. These effects are even more significant in the case of AMI, where a reduction in preload and afterload is synonymous with a reduction in oxygen consumption and the improvement of peripheral perfusion (with the consequent restoration of metabolic balance) leads to a reduction in myocardial ischemic damage induced by acidosis. The subsequent fundamental concept is to use reperfusion of the ischemic area to return it to its pre-ischemic state. It is now widely accepted that ventricular function after myocardial ischemia depends on the type of reperfusate and the method of reperfusion, instead of the duration of ischemia. Before revascularization, pre-treatment of the ischemic area with normal temperature whole blood enriched with energetic substrates and membrane stabilizers is currently the method most widely reported in the literature[10].

The literature contains only rare reports of AMI patients treated primarily with surgery[3,4]; there are more frequent reports of the results regarding patients who undergo revascularization because of the failure of medical or cardiological interventional treatments[11]. Furthermore, it is impossible to compare the results of prospective studies, which include patients undergoing early surgery, with those of retrospective studies in which the indication for aortocoronary bypass surgery is exclusively based on the failure of non-surgical revascularization techniques[12]. Nevertheless, it is important to note the progressive improvement in the results over time: the earlier surgical indication and the use of the myocardial protection protocol according to Buckberg led to a reduction in the mortality rate[6,13] and a significant recovery of left ventricular contractile function.

The analyses carried out on the largest study populations indicate the following as risk factors and determinants of the outcome:

the severity of hemodynamic impairment, age, and stenosis of the left main coronary artery[11];

anterior AMI in patients unsuccessfully treated with thrombolysis;

the time interval between the onset of pain and revascularization[3,4];

the preoperative ejection fraction[14].

Recent acquisitions and further developments

All the data show the importance not only of myocardial rest (muscular rest) during an ischemic event, but also of metabolic rest , achievable with a controlled perfusion during surgical procedure which both scavenges toxic metabolites from the myocardial vascular bed and gives new substrates to it for metabolic recovery, in this way unloading the myocardium from an intense metabolic work in a critic perfusion phase. It is essential to control the quality and quantity of perfusate given to the ischemic myocardium, so that some authors including Buckberg have suggested a method for controlled reperfusion without thoracotomy[15,16]. With the aid of extracorporeal femoro-femoral circulation, femoral transaortic left ventricular vent and an intracoronary perfusion catheter, the authors proposed a method to perfuse an ischemic portion of the myocardium in the catheter laboratory. In this experimental study the results did not differ from those of reperfusion with thoracotomy.

Other authors have recently proposed to perform revascularization during the acute phase of myocardial infarction without the use of cardiopulmonary bypass, in selected patients[17]. The selection was by virtue of the patient s anatomic conditions: disease involving marginal branches and surgical disease of the mitral valve were contraindications to the off-pump procedure. These patients underwent this procedure within 1 week of the infarction. Renal failure and preoperative cardiogenic shock were identified as independent predictors of overall mortality, on the other hand previous myocardial infarction and operation within the first 48 hours were independent predictors of overall unfavorable outcome events.

Another recent experience[18] suggests that revascularization without cardiopulmonary bypass could be preferable, due to the fact that it carries lower mortality than surgery with cardiopulmonary bypass, but the trade-off includes rates of recurrent angina, reintervention and late mortality.

Controlled reperfusion methods seem to be compatible with the use of arterial conduits, allowing to improve long-term results[17,19], due to the utilization of retrograde perfusion[20].

Timing of surgery remains an important factor also if the possibility of controlling reperfusion of the infarcted area seems to be able to salvage the stunned myocardium beyond this time limit. Some authors[14] demonstrated that myocardial revascularization is safe at any time after myocardial infarction in patients with an ejection fraction 50%, but should be delayed by at least 4 weeks if ejection fraction is < 50%. Timing itself is strictly dependent on the preoperative status of coronary circulation, by means of collateral flow, end-diastolic pressure and wall thickness. The poor predictability of the functional coronary circulation in an acute ischemic syndrome can justify an aggressive treatment because of the recruitment of patients in the positive range of the bias.

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