Surgical Treatment of Acute Myocardial Infarction

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This historical article review takes the reader from the introduction of surgical treatment of acute myocardial infarction (AMI) by the saphenous vein graft technique, starting in April 1968, through the progress that has been made to date in preventing and combatting the devastating effects of AMI and up to current treatments.

Acute Coronary Insufficiency (Impending Acute Myocardial Infarction and Myocardial Infarction) Surgical Treatment by the Saphenous Vein Graft Technique

by Favaloro, Efler, Cheanvevchai, Quint, and Sones Jr. (8)

ABSTRACT

The development of direct coronary artery surgery by the saphenous vein graft technique for the first time provides a method that immediately increases the supply of oxygen to the myocardium. As a result, the area of myocardial infarction no longer depends only upon oxygen consumption.

Emergency surgery was performed on 29 patients from April 1968 to May 1971; 18 operations were performed upon patients with impending myocardial infarction and 11 upon patients with acute myocardial infarction. Nineteen patients underwent coronary cineangiography before the acute episode; 9 were studied during an acute episode. Patients with impending myocardial infarction were operated on within 24 hours of the acute episode. Nine patients with acute infarction were operated upon within 4 to 5 hours, 1 within 8 hours and 1 within 10 hours. Three patients died after the operation; 2 in the group with impending myocardial infarction and 1 in the group with acute infarction. Twelve patients underwent repeat cineangiographic evaluation. All grafts but 1 were open. In the group with impending myocardial infarction, postoperative left ventriculography showed good function of the left ventricle. In the group with acute myocardial infarction, 4 patients showed good function of the left ventricle. In 1 the ventricle was unchanged, and in 2 impaired contraction was demonstrated.

Although the present clinical experience is limited, certain conclusions can be made: (1) Emergency coronary cineangiography can be performed with minimal risk. (2) Patients with impending myocardial infarction can undergo operation with a low mortality rate and minimal complications. These patients are ideal candidates. The operation can prevent myocardial infarction. (3) When operations are performed within 6 hours of an acute myocardial infarction, most of the heart muscle can be preserved. (4) In patients with acute myocardial infarction and cardiogenic shock, assisted mechanical circulation is mandatory.

50th Anniversary Historical Article

INTRODUCTION

In this edition of the Journal, we release the sixth in a series of reviews of influential articles that have been previously published in ACC journals, including the American Journal of Cardiology (from 1958 to 1982) and JACC (from 1983 to the present). The publication of these articles is only one aspect of the ACC's 50th anniversary commemoration, which highlights 50 years of leadership in cardiovascular care and education. The articles are intended to encourage reflection on the remarkable progress made in cardiovascular medicine over time, as well as to acknowledge the amazing prescience of some early investigators in anticipating and, in many cases, later guiding developments in their field.

The working group responsible for selecting these articles and asking reviewers to write editorials solicited suggestions from the ACC's clinical committees and individual members. The group achieved consensus fairly easily, including whom the group should ask to prepare the accompanying editorials. We initially drew up a list of 14 general areas to cover in this series, but later found that there are several major areas of modern cardiology, prominently molecular cardiology, in which the truly landmark articles have, alas, not yet been published in JACC. Therefore, the working group decided not to categorize by subject, but instead, to concentrate on the most important articles.

The working group, a task force of the Subcommittee for the Commemoration of the ACC 50th Anniversary, owes a great deal to Ms. May A. Roustom and the efficient and tireless staff at Heart House for facilitating this project. We also wish to thank all who suggested articles and, most important, the authors who prepared reviews for their willingness to contribute their time and wisdom.

Influential Articles in JACC Working Group

Sharon A. Hunt, M.D., F.A.C.C.
Rick A. Nishimura, M.D., F.A.C.C.
H.J.C. Swan, M.D., Ph.D., M.A.C.C.
Michael J. Wolk, M.D., F.A.C.C.

From the Favaloro Foundation, Buenos Aires, Argentina.
My clinical experience started in April 1968. The first patient was described in detail in one of my publications (9). The definite limitations of the medical treatment available in those years were also emphasized (8):

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Review

During work on myocardial revascularization using the Vineberg approach in the early 1960s, I was puzzled by the discrepancy between the clinical and pathologic findings in patients who died suddenly or within the first hours of the postoperative period as a consequence of a documented acute myocardial infarction (AMI). At autopsy, which I usually performed with the members of the pathology department, I was not able to circumscribe the area of the infarction macroscopically. Not even by means of routine microscopy was it possible to define the acutely infarcted area. Electron microscopy showed afterward that most of the cells were intact.

In 1966, Cox et al. (1) demonstrated by dehydrogenase staining techniques that 6 h after ligation of the anterior descending branch of the left coronary artery, only ischemia was detected in areas exhibiting evidence of pathologic change. In 1968, a complete detailed report confirmed the preliminary results (2). Meanwhile, the contributions of Braunwald and Sonnenblick (3–7) elucidated the physiopathological relations of the descending branch of the left coronary artery, only ischemia was detected in areas exhibiting evidence of pathologic change. In 1968, a complete detailed report confirmed the preliminary results (2). Meanwhile, the contributions of Braunwald and Sonnenblick (3–7) elucidated the physiopathology of the ischemic myocardium. Clearly, survival of myocardial cells was related to oxygen consumption.

An overview of the knowledge acquired by that time was carefully summarized in the article reviewed here (8). The definite limitations of the medical treatment available in those years were also emphasized (8):

The development of direct coronary artery bypass graft (CABG) by the saphenous vein graft technique has for the first time provided a method that immediately increases myocardial oxygen supply. As a result, the evolution of the area of AMI no longer depends only upon myocardial oxygen consumption. These fundamental principles led the Cleveland Clinic team to perform emergency operations upon patients with acute coronary insufficiency.

My clinical experience started in April 1968. The first patient was described in detail in one of my publications (9). Despite the new facilities, we continued to have a waiting list. Those patients with critical obstructive lesions were lodged generally in the Bolton Square Hotel and were operated on as soon as possible.

I usually arrived at the Clinic at 7 a.m. One day in April 1968 the resident on call told me that one of the patients had experienced severe chest pain at 6 a.m. and was in poor condition. This patient's previous coronary arteriogram had shown a severe lesion near the beginning of his left anterior descending artery. We went to his room at the hotel and found him to be cold and sweating, slightly cyanotic and breathing rapidly and with difficulty. His arterial pressure was low. Given his previous history, we were certain that he was experiencing an AMI, which was confirmed by the electrocardiogram.

While the patient was on his way to the coronary unit, I went to B10. Fortunately, Sones had arrived by then and I proposed the possibility of performing an emergency operation, because the patient had been referred to him for cinecoronary angiography. As usual, his love and respect for his patients caused him to raise some objections which I refuted, telling him of my own observations and reviewing the published experimental work. My enthusiasm proved to be stronger than his objections, and he accepted my proposal.

When the patient had been transferred to the sixth floor I explained the situation to his family, who accepted the decision to operate. As in so many emergencies, the whole team moved quickly and we had him on extracorporeal circulation in a few minutes. On opening the pericardium we could see that the anterolateral wall of the left ventricle did not contract; the ventricle appeared to be distended and somewhat cyanotic. It was necessary to decompress the heart as soon as possible, so we gently placed a medium-sized catheter into the left ventricle by way of the right upper pulmonary vein and continuously aspirated the arriving blood.

In the light of past experience we made a bypass from the aorta to the anterior descending artery, and we could see how the wall of the left ventricle gradually recovered its color and contractility. We kept the patient on extracorporeal circulation, with his ventricle undergoing decompression for half an hour. His heart began to contract vigorously and we gradually reduced the flow from the pump until his ventricle was maintaining the entire flow by itself. The blood pressure showed constant improvement and it was not necessary to administer medication. On the following day the patient was extubated. The electrocardiogram showed only a minimal alteration in the anterior wall."

In 1970, I summarized our early experience in Chapter 10 of one of my books (10). The paper reviewed here was accepted in July 1971, shortly after my return to Argentina from the U.S. In this article, 29 patients were analyzed; 18 operations were performed among patients with impending AMI within the first 24 h, and 11 operations were performed on patients with AMI. Twenty-eight years later, the accuracy of the conclusions still surprises me. These conclusions were the outcome of our analysis of a very short series; over time, they were proved right, so they appear to be, in fact, the corollary of many years of practice.

In the period immediately following publication of this article, a number of contributions appeared that indicated that the operation could be performed with low operative mortality and good clinical results (11–20). The Spokane group (DeWood et al.) accumulated the largest experience (21–25). DeWood et al. (26) presented a complete report of 387 patients (200 on medical treatment and 187 who underwent emergency coronary artery bypass graft surgery [CABG]) with a hospital mortality of 11.5% versus 5.8% in the medical and surgical groups, respectively. If the operation were performed <6 h, the mortality was only 2%. The
10-year follow up demonstrated a 41% mortality rate in the medically treated group versus a 27% mortality rate in the surgical group.

We continued our efforts in Buenos Aires. Experiments with monkeys (27) confirmed that within 6 h, most of the myocardial muscle could be reconstructed if the blood supply were re-established. Before 1983, 583 patients were studied with cinecoronary angiography in the acute and subacute phase. These studies again confirmed that coronary arteries can be visualized in an emergency procedure following the original contribution of Begg et al. (28). In 1977, we first presented a description of the cinecoronary angiogram in patients with post-AMI angina (29). This description clarified proper surgical indications, and a detailed analysis of the surgical experience was presented in another of my publications (30).

Three decades of progress. The introduction of fibrinolytic agents has opened a new era in the treatment of AMI. The results of early clinical and randomized trials and subsequent large-scale randomized trials demonstrated that when intravenous thrombolytic therapy is administered within 12 h after onset of symptoms, hospital mortality is reduced and survival advantages persist. Late mortality is low, particularly when compared with series before the use of thrombolytic agents (31). Nevertheless, it has become clear that even with the best regimen, early true reperfusion (Thrombolysis in Myocardial Infarction, TIMI, flow 3) occurs in a disappointingly low percentage of patients (~50%).

It is a mistake to report TIMI 2 and TIMI 3 flow together because TIMI 2 flow should be considered an inadequate result of therapy (32-36). The European Cooperative Study Group (34) showed that at five years, patients with TIMI 2 flow had a mortality incidence similar to that of those with TIMI 0 and 1 flow.

The incidence of recurrent ischemic events reinfarction and reocclusion after thrombolysis remains high. It is hoped that molecular biology and genetic engineering will contribute to a new generation of thrombolytic agents (reteplase, staphylokinase, t-PA-scu-PA chimera, bat-t-PA, TNK mutant, antibody-targeted plasminogen activators and antibody targeting of adjunctive agents) that will improve our present results. Recently, GUSTO III angiographic results have shown that reteplase (r-PA) achieved better early patency than alteplase (t-PA) but that t-PA was associated with an increased probability of late reocclusion (37).

It is possible that the combination of potent inhibitors of the platelet glycoprotein IIb/IIIa receptor (38) and thrombolytics will increase the degree of lysis and lessen rethrombosis. The result of the TIMI 14 trial showed that TIMI 3 flow increased to 76% when abciximab was administered with t-PA (60-min infusion) (39). The CABG has also been used after thrombolysis for AMI. Several publications confirming its use appeared in the early- and mid-1980s (40-42). An important article was published in 1995: the TIMI II Phase II Trial (43).

A review of all the publications about these advances indicates the following:

1) Intravenous thrombolytic therapy for evolving AMI is associated with a significant increase in subsequent coronary revascularization when compared with patients receiving conventional therapy (44-46);

2) The CAGB can be performed on patients at high risk with acceptable operative mortality (except in emergency situations) within the first 24 h. Most of the patients in the emergency group are in poor hemodynamic condition and many are in cardiogenic shock. In the TIMI population, 58% required an intracardiac balloon. Recently, analysis of the SHOCK (SHould we emergently revascularize Occluded Coronaries for cardiogenic shock) trial registry (47) demonstrated that the combination of thrombolytic therapy, intraaortic balloon counterpulsation, CABG and percutaneous transluminal coronary angioplasty (PTCA) decreased the mortality of this high-risk group of patients to 46.9% and

3) Blood loss is greater when CABG is performed on patients receiving thrombolytic agents, particularly if surgery is performed during the first 24 h, when hemorrhagic events and reoperations are common. For this reason, the cooperation of an expert in coagulation therapy is mandatory in the operating room and in the immediately postoperative recuperation.

The use of PTCA in AMI increased significantly after the report of the PAMI trial in 1993 (48), which compared the results of primary PTCA with those of thrombolytic therapy for AMI. Several publications, including a critical analysis reported by Michels and Yusuf (49), demonstrated a significant reduction in mortality with PTCA. When PTCA was compared with thrombolytic therapy, PTCA resulted in smaller infant size and better preserved left ventricular function. Unfortunately, although it reduced the incidence of recurrent angina, reinfarction and reocclusion, the incidence of these factors still remained high in PTCA patients (50). Furthermore, the incidence of restenosis is also high. Horrigan et al., in a meta-analysis of 860 patients, found that average incidence of restenosis after PTCA was 43% (51).

In later reports (although with smaller series of patients), it was shown that stents can be used after PTCA in patients with AMI with a high success rate (52-61). The results of the multicenter PAMI Stent Pilot Study confirmed those of earlier contributions. Follow up at six months (62) demonstrated that in a comparison between 452 patients treated with heparin-coated stents versus 448 patients treated with PTCA alone, the addition of stents resulted in greater luminal diameter; reduced angiographic restenosis (16.9% vs. 35.9%); and also reduced combined end point of death, recurrent AMI, disabling stroke and target-vessel revascularization due to postprocedural angina or ischemia (12.4%
vs. 20.1%). Nevertheless, stents cannot be applied in all patients, mainly because the arterial diameter must be >2.5 mm. In the PAMI Stent Pilot Study, 31% of the patients were considered ineligible for stent placement “if they had small vessels (diameter <2.75 mm), if >2 stents were required, if there was a huge residual thrombus, if there was a possibility that a stent would be needed in the ostium of the left anterior descending coronary artery or left circumflex, if major side branches were in jeopardy, or if delivery or expansion of the stent might not be feasible.”

**Treating AMI 30 Years Later.** It is clear that today, patients with AMI can be treated with thrombolysis, PTCA or CABG. As is the case with many other issues in medicine, opinions on the appropriate use of alternative modalities are divided. On the basis of a critical analysis of the guidelines for the management of patients with AMI (63) and knowledge acquired throughout the years, I outline a number of suggestions for the proper treatment of patients with AMI as follows:

1) A clinical examination of the AMI patient that only takes a few minutes gives us important information. We know that infarct-related mortality increases with age, female gender, a history of chronic angina, previous infarction, hypertension, diabetes and presence of peripheral vascular disease (64–68). Significant tachycardia (>100 per min), hypotension, signs of congestive heart failure, atrial and ventricular arrhythmia, persisting angina and persisting ST segment depression indicate that patients in this category are at high risk. The TIMI Phase II coinvestigators (69) analyzed the presence of eight risk factors before thrombolytic therapy was administered: age >70 years, female gender, a history of diabetes mellitus or previous AMI, electrocardiographic evidence of evolving anterior infarction or atrial fibrillation, evidence on physical examination of mild pulmonary congestion, hypotension (systolic pressure <100 mm Hg) and sinus tachycardia (heart rate >100 beats/min). Among 3,261 patients, 864 presented 0 risk factors, 13% (1,384 patients); for two risk factors, 7% (689 patients); for three risk factors, 13% (231 patients); and >4 risk factors, 17.2% (93 patients). Therefore, clinical examination and the presence of risk factors, which are easy to remember and do not have a numeric score (70,71), can clearly categorize patients at low and high risk. A 12-lead electrocardiogram for primary screening will differentiate between the groups.

2) Echocardiograms in the emergency room are mandatory. The contribution of Sabia et al. (72,73) demonstrated that regional wall motion abnormalities (RWMA) carried out with two-dimensional echocardiography increase the diagnostic yield for AMI. Although the finding of RWMA cannot differentiate between ischemia and necrosis, it can define the extent of myocardium involved and provide information of the myocardium remote from the region of acute injury. The analysis of the left ventricular systolic dysfunction (LVSD) can help cardiologists predict events within 48 h of admission (73). Events occur in 26.9% of the patients when LVSD is present, versus 3.3% when LVSD is absent.

3) The laboratory also plays a role in establishing the final diagnosis. Rapid blood bedside assays of cardiac specific troponin T (cTnT) and I (cTnI) are now available.

4) Balloon-flotation right-heart catheter monitoring with measurement of pulmonary capillary wedge pressure and cardiac output is very helpful in patients with early signs of left ventricular deterioration. Of course, its use is mandatory in patients with cardiogenic shock.

As a consequence of this analysis (Fig. 1), patients at high risk should be sent directly to the cardiac laboratory for emergency cinecoronary angiography. After carefully reviewing the study, most patients will be treated with PTCA and a stent. Nevertheless, patients with severe left main coronary artery trunk obstruction, left main equivalent or three severe proximal obstructions should be sent for CABG. It is important to remember that survival after AMI determined by the infarct size and the capacity of remote, nonischemic myocardium to support the systemic circulation by hypercontractility (74). A recent report by Jaarsma et al. (75) showed a 69% mortality rate for patients who did not have remote hypercontractility, and a previous contribution by Schuster and Bulley (76) reported a 72% late mortality rate for patients with "ischemia at a distance." Of course, patients with cardiogenic shock should be sent immediately to the cardiac laboratory (after insertion of an intraaortic balloon). The PTCA procedure is at the frontline to reduce the extremely high mortality rate.

Patients in the low risk category with ST segment elevation or left bundle branch block who have no contraindications should be treated with intravenous thrombolytic therapy. Their evolution should be followed closely because the preliminary stratification can change within a few hours. Early discharge after thrombolytic therapy can be accomplished in low risk patients with uncomplicated AMI, but a submaximal test (five metabolic equivalents [METs]) is indicated before discharge in patients who can exercise. Patients with a positive test should be sent to the cardiac laboratory where the decision for the most suitable treatment can be made.

Patients who cannot exercise may be investigated (with caution) by pharmacologic thallium–201 or dipyridamole echo, or they may be sent directly to the cardiac laboratory. They represent 10% to 22% of survivors of AMI. Such patients have a high mortality rate and a high incidence of recurrent events (77–81). Between three and six weeks later, an exercise test (full Bruce protocol with or without thallium–201) or exercise echocardiography should be performed. As many as 35% of patients with a negative
predischARGE submaximal exercise test may provide evidence of myocardial ischemia on a more strenuous testing (82,83). Patients with negative tests are followed under medical treatment (mortality at one year <2%) (84–87); patients with positive tests should be sent for catheterization (mortality at one year is as high as 15%) (85). Recurrent ischemic events are always a clear indication for cinecoronary angiography. Patients with unsuccessful or complicated PTCA will require CABG.

Both PTCA and CABG can work together for the benefit of patients during the early days after of AMI. In patients with multivessel disease, PTCA and stenting can be done first at the culprit lesion. A few days later, when the enzymes are close to normal levels, multiple CABGs can be performed without increasing the operative risk. This double-step procedure has been applied in our institute for the past three years.

Naturally, it is understood that a significant number of patients will be kept in medical treatment. Approximately 33% of U.S. patients with AMI received thrombolytic therapy. The analysis of the NRMI showed that early preliminary PTCA was performed in 5.9% of the patients; emergency CABG was used in 0.6%. During hospitalization, 20.5% and 18.8% underwent PTCA and CABG, respectively (Rogers, WJ, personal communications November 1996). In the GUSTO trial (88,89), 72% of 21,772 patients underwent angiography before discharge and of those, 59% underwent revascularization (70%, PTCA; 30%, CABG). The TIMI IIIb trial (90) presented similar results: out of the conservative strategy group (733 patients), 64% had catheterization within six weeks. Revascularization was performed in 49% (PTCA in 26% and CABG in 23%). These three trials can give us a general idea of the present approach for patients with AMI.

CONCLUSION

In conclusion, PTCA and thrombolysis are at the front line for emergency treatments in most of the patients with AMI. Coronary artery bypass graft is indicated in a small number of patients within the first 24 h. However, the number of operations increases significantly in the following weeks. The progress that has been made in the therapy of AMI over the 28 years since the publication of the first article documenting the efficacy of CABG is a great example of the convergence of a variety of research fields treating a common clinical problem. I am pleased to see that at present the devastating effects of AMI have been ameliorated by the combined efforts of the clinician, the interventional cardiologist and the cardiovascular surgeon.

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