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50th Anniversary **Historical Article**

Myocardial Infarction and Coronary Care Units

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Treatment of Myocardial Infarction in a Coronary Care Unit: A Two-Year Experience With 250 Patients

by T. Killip, III, J. T. Kimball (1)

ABSTRACT

The results of treatment of 250 patients with established acute myocardial infarction in a coronary care unit in a university hospital are described. The criteria for diagnosis have been carefully defined. In 62 percent of patients admitted with a tentative diagnosis of acute infarction, the initial impression was confirmed. Fifteen percent of patients admitted to the unit were classified as having possible infarction; in this group, the mortality rate was 3 percent. A classification of functional severity based on clinical evidence of heart failure or shock is presented.

Morbidity and mortality in acute myocardial infarction are related to the functional severity of the illness. Although arrhythmia is common, the overriding importance of five life-threatening arrhythmias is emphasized. Mortality of patients in the coronary care unit was not improved in comparison to those treated under regular care until strong central direction of therapeutic programs, immediate treatment of arrhythmia in cardiac arrest, and delegation of some medical authority to trained nurses was accomplished. The change in concept of the purposes and practices of special coronary care from resuscitation to prevention of arrhythmia is emphasized.

The mortality in myocardial infarction complicated by shock remains high. In the absence of shock, aggressive medical treatment in the coronary care unit reduced mortality from 26 to 7 percent. The implications of these data in the management of patients admitted to a hospital with a diagnosis of acute myocardial infarction are discussed.

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Review

In 1967, Killip and Kimball (1) published an article that helped confirm the role of the coronary care unit (CCU) as an important tool in the management of patients with acute myocardial infarction (AMI). They asserted that the major benefit of such a specialized unit is the timely recognition and immediate treatment of life-threatening arrhythmias. Most importantly, this landmark study established a method for early risk stratification, or classification, of patients admitted to CCUs with AMI, eventually desig-

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INTRODUCTION

In this edition of the *Journal*, we release the fourteenth 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.
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nated as the the Killip classification but perhaps better expressed as the Killip and Kimball classification or index.

The recognition of the importance of arrhythmias is attributed to Samuel Levine (2), who in the 1920s was one of the first physicians to outline the association between ventricular arrhythmias and sudden death. Treatment of sudden cardiac arrest, however, was not described until two decades later, when several successful open chest resuscitations were reported. One such resuscitation described by Beck and colleagues (3) was of a young boy who developed ventricular fibrillation while undergoing surgery and was successfully cardioverted with electrical shock. In 1956, Beck (4) reported the successful cardioversion by open thoracotomy of a 65-year-old man with ventricular fibrillation in the setting of myocardial infarction (MI). This advance was significant because it implied that patients with potentially fatal MIs could be resuscitated and managed through the crisis. Several other successful resuscitations were reported over the following five years (5).

In 1960, several important advances laid the groundwork for the development of the CCU. These developments included the technique of closed chest cardiopulmonary resuscitation and the use of the continuous telemetry monitor with an alarm system allowing for prompt attention to significant arrhythmias by hospital personnel. The first description of the CCU was presented by Julian to the British Thoracic Society in 1961 (6). The response was positive, and monitoring of patients with AMI in specialized units began in 1962. The first CCU in the U.S. was started by Day in Kansas, and another, not long afterward, by Meltzer in Philadelphia.

In their landmark article, Killip and Kimball (1) described their experience with 250 patients with AMI treated in a specialized CCU. Patients with definite MI, as defined by electrocardiogram findings and laboratory enzyme results of SGOT, SGPT and LDH, were treated either on a regular ward or in a specialized CCU. Each group was subdivided according to severity of cardiac failure, with particular regard for the presence or absence of cardiogenic shock. The first analysis of mortality and morbidity data was set forth after eight months of CCU operation. One hundred patients with definite MI treated in the CCU were compared with 100 patients treated in a regular ward. In the initial comparison, the mortality of the two groups was comparable. However, after certain decisive policy changes in the CCU, significant benefit was obtained. Nurses were authorized to apply precordial shock if a physician was not available within 60 s, and a clear protocol for treatment of CCU patients was given to the in-house physician by the senior physician. After these modifications, a significant improvement in mortality was observed in the next 150 CCU patients who were not in cardiogenic shock. Most notably, the mortality rate decreased from 26% for patients treated in a regular ward to 7% for those treated in the CCU. In addition, patients who suffered a cardiac arrest were more likely to survive if the event occurred in the CCU. These findings confirmed the importance of the prompt recognition and treatment of significant arrhythmias in patients with AMI.

Although the numbers were not large, for those patients in cardiogenic shock, no benefit from intensive cardiac care in terms of morbidity or mortality was detected. The mortality for these patients was quite high—69% in the patients managed on the regular floor and 85% for those treated in the CCU. The treatment of such patients remains a considerable therapeutic challenge today. Although there is now evidence that the 30-day survival rate is increased in patients with AMI complicated by cardiogenic shock who undergo revascularization, the overall mortality remains high. It seems likely that until further treatment options become available for these patients, prevention of such complications as cardiac rupture and intractable congestive heart failure will be of fundamental concern in the management of high-risk patients with MI.

Although Killip and Kimball (1) reported improved mortality and morbidity in patients with AMI treated in the CCU, the effectiveness of these units continued to be debated over the following decades. Killip and Kimball were not alone in reporting benefit in mortality. Others who directly compared patients treated in the intensive care unit with those treated in regular wards and found a benefit in terms of mortality included Meltzer (7) and Brown and MacMillan (8). In addition, since 1967, when the CCU became widely instituted in the U.S., the mortality of patients with AMI has decreased steadily in those older than 35 and those younger than 65 years of age. This finding, however, cannot be attributed to intensive care alone, as many advances have occurred simultaneously, including the primary and secondary prevention of atherosclerotic disease and the medical and interventional management of acute coronary syndromes. In the late 1970s, Hill and associates (9) compared AMI patients treated at home with those treated in the hospital. They found no significant difference in mortality for the two groups. A notable qualification of this study is that a significant subgroup of patients was excluded from the trial. These patients had a higher mortality than either of the other groups. This finding suggests that the MI was not severe enough in the included groups to detect a benefit from the management in an acute CCU. In addition, this trial, as well as other similar studies, was conducted over 20 years ago, before vigorous techniques for controlled trials had been established. It now seems clear that the prevention of arrhythmic death in those patients who are at high risk is best carried out in the CCU.

I do think, however, that there is another useful aspect of the article by Killip and Kimball (1)—namely, the heart failure (or severity) index they developed. This clinical index seems to have stood the test of time. It was an attempt to develop a bedside classification of the integrity of left ventricular function. Obviously it is not precise, but in large population studies it seems to work: there is a direct

relationship between the classification and mortality. A number of studies appear to have validated this index with respect to mortality. There is clearly something useful in the classification or index that Thomas Killip and John Kimball developed.

It is possible that some of the less crude and more accurate invasive approaches used in the CCU, such as the routine use of the flow-directed Swan-Ganz catheter for evaluation of ventricular function, may actually increase mortality in some cases. The use of the Swan-Ganz catheter in patients in intensive care units has been widely debated. Several retrospective studies have addressed the benefit of the Swan-Ganz catheter and have detected adverse outcomes in some patients. No prospective clinical trials have been undertaken to date. Some investigators have called for a moratorium on the use of the Swan-Ganz catheter until such a study is completed (10). It is possible, however, that because data are often made available from the pulmonary artery catheter, which is useful in specific clinical scenarios, such a moratorium would not be wise (11). Generally, use of the Swan-Ganz catheter should be limited to a small number of absolute indications in which a specific question is answered or by which drug therapy is guided. The most obvious indication for cases of AMI would be in the management of patients in cardiogenic shock who will be treated with positive inotropic intravenous agents and diuretics. The length of time the catheter is left in place is also important. A shorter duration would be less likely to lead to such complications as bacteremia and right-sided endocarditis.

This landmark article by Killip and Kimball (1) was important in establishing the benefit of intensive care for patients with AMI. Those patients at high risk for sudden death are the most likely to benefit from such specialized care. Another useful aspect of the article was the severity index they developed. Today it is my belief that under specific circumstances the use of an invasive monitoring device such as the Swan-Ganz catheter is important in the management of certain cardiac patients. However, a prospective randomized controlled trial may be useful in confirming this benefit.

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