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REVIEW ARTICLE

Issues in Contemporary Cardiac Rehabilitation: A Historical Perspective

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Cardiac rehabilitation consists of exercise, psychosocial support and education and is prescribed most often for patients with coronary heart disease. Its purpose is to facilitate readaptation to normal life through the achievement of maximal functional capability and to reduce heart disease risk factors. It began historically with progressive ambulation after myocardial infarction and by 1980 became a standardized inpatient therapy performed according to a stepped procedure. Predischarge exercise testing was added and has become a meaningful contribution to the concept of risk stratification after an acute coronary event. Rehabilitation has subsequently become part of the outpatient environment and is delivered by multiple models. Meta-analyses have shown that rehabilitation reduces overall and cardiovascular deaths by about 20% and sudden death by about 37% during the year after an acute myocardial infarction. The significance of this, however, must now be modulated by the dynamic role of aggressive coronary intervention. Selection for such intervention has become an important adjunctive aspect of rehabilitation. Newer findings suggest that those stratified at low risk will benefit most by the modification of coronary risk factors, and that patients previously thought to be poor candidates for rehabilitation (such as those with significant left ventricular dysfunction and low work capacity) may experience substantial relative functional benefit. Beyond risk stratification, important contemporary issues include surveillance of patients after angioplasty, the effectiveness of rehabilitation in the attenuation or reversal of both native and vein graft atherosclerosis and consideration of such currently emphasized end points as quality of life and economic evaluation.

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In the minds of many cardiologists, cardiac rehabilitation is subordinated to more aggressive cardiovascular therapeutics. Historically, rehabilitation derived from the concept of early mobilization after acute myocardial infarction. This led to the belief that the primary purpose of rehabilitation was exercise conditioning. The aim of this review is to trace the evolution of the technique and explain how it has evolved far beyond exercise conditioning to include risk stratification, quality of life and life-style modification. Cardiac rehabilitation, through its effects on the dynamics of cardiovascular function and on coronary disease risk factors, is integral to the treatment of most cardiac conditions and should accompany other contemporary modes of cardiac therapy.

Milestones of the Past

Early mobilization after myocardial infarction. After the clinical description of myocardial infarction by Herrick in 1912, patients were generally confined to bed rest for 2 months. The fear was that physical activity would lead to the formation of ventricular aneurysm, heart failure, cardiac rupture and sudden death (1).

In the late 1930s, Mallory and associates (2) described the pathologic evolution of myocardial infarction as a process maturing over 6 weeks from initial ischemic necrosis to formation of a stable scar. This time characterization of infarct evolution reinforced the prevailing clinical practice of strict bed rest for 6 to 8 weeks after acute myocardial infarction. Activities defined as strenuous, such as stair climbing, were restricted for protracted periods, sometimes indefinitely. Return to a normal life-style, including resumption of gainful employment, was rare.

By the late 1940s, studies that questioned the efficacy of prolonged bed rest appeared (3,4). Levine and Lown (5,6) advocated the use of chair therapy as an alternative to prolonged bed rest. The proposed rationale was that the dependency of the lower limbs led to reduced venous return, a decreased stroke volume and a reduction of cardiac work. The belief of these investigators that sitting decreased cardiac work was slightly erroneous because this position results in a smaller increase in oxygen consumption than does the supine position. However, this added energy requirement is minimal and is more than offset by the advantages of early mobilization. Nevertheless, the chair therapy of Levine and Lown was one of the first departures from the practice of strict bed rest.

Newman and coworkers (7) defined early ambulation as 3 to 5 min of walking twice daily beginning 4 weeks after

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infarction. Brummer and colleagues in 1956 (8) were among the first to report on the use of early ambulation within 14 days of the acute event. In 1961 Cain and associates (8a) reported on the efficacy and safety of an early graded activity program. Thereafter, clinicians gradually became aware that early mobilization might not be harmful and, in fact, could avoid some of the complications of bed rest, such as pulmonary embolism and deconditioning (9). Subsequent studies have shown that the adverse hemodynamic effects of bed rest are related to the disorganization of the normal upright response to gravity (10) and are not related to alterations in sympathetic or pressor responses (11) or to muscular deconditioning as such.

Coincident shortening of hospital stay. By the late 1960s, 3 weeks of hospitalization after myocardial infarction was routine in the U.S. The early 1970s saw a flurry of research related to early mobilization, particularly in England and in countries where the cost of hospitalization had already become a major social welfare issue. Groden et al. (9) and others (12,13) demonstrated the similarity in the outcome and safety of early ambulation therapy, but the studies were not prospective or randomized. Controlled studies of early ambulation by Boyle and Lorimer (14) and others (15–17) revealed no significant difference in the occurrence of angina, reinfarction, heart failure or death. Bloch et al. (16) found greater disability up to 1 year later in patients who had not had early mobilization.

Abraham and colleagues (17) found that early ambulation was beneficial regardless of complications such as angina or congestive heart failure during the early infarction period; they also found that morbidity and mortality were much higher in patients with a complicated than in those with an uncomplicated course (1). The most important clinical predictors for complications were prior myocardial infarction and congestive heart failure or cardiogenic shock (1). It is now believed that ambulation should be deferred in these patients until they have been stabilized medically and then increased gradually under close observation (18). Table 1 summarizes criteria for later classification of patients at low, intermediate or high risk.

As early ambulation was increasingly applied, it evolved into what we currently define as phase I or inpatient cardiac rehabilitation (19). Wenger et al. (19) did much to systemize the technique and to promote it for clinical use. Activities performed in the coronary intensive care unit were limited to 2 METs. The MET (metabolic equivalent) describes total oxygen requirements by the body (1 MET = 3.5 ml O_2 consumed/kg body weight per min). In general, METs correlate with myocardial oxygen demand, but the relation varies according to the type of activity. Upper limb activities or isometric activities may invoke higher myocardial oxygen demands than do lower limb activities. Activities that require fewer than 2 METs include self-care activities, such as bed bathing, use of a bedside commode, chair sitting and passive and active range of motion. This portion of the

Table 1. Characteristics of Low, Intermediate and High Risk Patients

Low risk patients	
	After uncomplicated coronary revascularization
	≥7.5 METs 3 weeks after an ischemic event
	No ischemia, left ventricular dysfunction or significant arrhythmia
Intermediate risk	
	≤7.5 METs 3 weeks after an ischemic event
	Angina or 1- to 2-mm ST segment depression with exercise
	Perfusion or wall motion abnormalities with stress
	History of congestive heart failure
	More than mild but less than severe left ventricular dysfunction
	Late potentials present on signal-averaged electrocardiogram
	Nonsustained ventricular arrhythmia
	Inability to self-monitor exercise or comply with exercise prescription
High risk	
	Severe left ventricular dysfunction
	≤4.5 METs 3 weeks after cardiac event
	Exercise-induced hypotension (≥15 mm Hg)
	Exercise-induced ischemia >2-mm ST segment depression
	Ischemia induced at low levels of exercise
	Persistence of ischemia after exercise
	Sustained ventricular arrhythmia, spontaneous or induced

METs = metabolic equivalents.

experience usually is supervised by the unit nursing staff but sometimes involves a specialized rehabilitation team (20).

Formalization of phase I. Once transferred from the coronary care unit, the rehabilitation specialists usually supervise the activity regimen. They may be nurses, physical or occupational therapists or exercise physiologists with special training and experience (20). Surveillance of the response to early ambulation is facilitated by the use of telemetered electrocardiographic (ECG) monitoring (19). Untoward responses to activity include dyspnea, ischemic chest pain, arrhythmia or a disproportionate heart rate response to exercise (21). ST segment abnormalities during ambulation by nonstandardized telemetry monitoring may be misleading and require confirmation by 12-lead ECG recordings. The postexercise heart rate should remain within 20 beats/min of the rate at rest, and blood pressure should be within 20 mm Hg (1). A decrease in systolic blood pressure of ≥15 mm Hg below the baseline value at rest is worrisome. The inability to maintain or increase systolic pressure with a low work load suggests compromised pump function that may reflect either extensive intrinsic damage or large amounts of myocardium under ischemic stress. Any one of these findings warrants clinical reassessment. An appropriate response to a given level of activity indicates that the patient can be advanced safely to activities of greater intensity (19).

The major goal for the physical activity portion of the phase I program is to condition the patient for the exertional demands required after discharge (22). This is a reasonable task because most activities of daily living in the home environment require less than 4 METs. Stair climbing should be monitored and supervised until competency and safety

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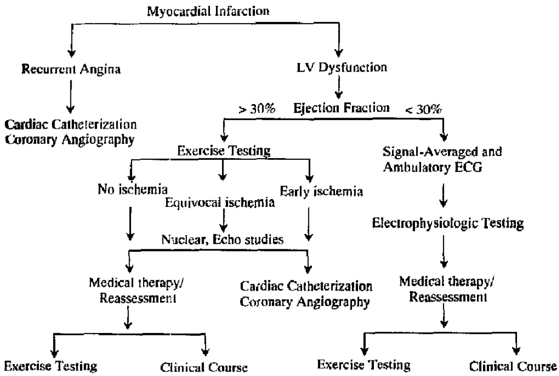

Figure 1. Scheme for risk stratification of patients after myocardial infarction. Reproduced with permission from Wenger NK: Risk stratification after myocardial infarction. *Myocardium* 1988;1(1):3–7. ©1988, PW Communications International, a division of Physicians World Communications Group. All rights reserved. ECG = electrocardiogram; LV = left ventricular.

are confirmed. Historically, activity was prescribed in rather rigid steps, and the MET level of each step was tied closely to the time elapsed after the event. Several early ambulation protocols defining from 7 to 14 steps are available (1,21). The exercises prescribed were correlated with various activities of daily living and educational and recreational activities.

Currently we advocate individualized exercise therapy by supervising progress closely with appropriate alterations in exercise frequency, time and distance. Because progress occurs in fractions of a MET and because patients may be fatigued from concurrent medical procedures or other activities, individualization seems suitable. Defined activity formats are useful where cardiac rehabilitation is not performed by specialists. Such formats provide an activities template and eliminate the need to write specific daily activity orders for every patient (21).

With time, the limits of activity have been extended safely, and from the mid-1970s to the mid-1980s, the length of hospital stay was shortened from 14 to approximately 10 days (23,24). Currently, length of stay for uncomplicated infarction in the U.S. is 6 to 7 days. This reduction has significant implications for outpatient rehabilitation programs.

Risk Stratification After Myocardial Infarction

Predischarge exercise testing. Exercise testing is important in assessing the status of patients who recover from an acute myocardial infarction (25). It is especially useful for assessing and reassuring patients about their ability to return to work and normal recreational activities (22). Early studies (26,27) of exercise testing demonstrated the feasibility and safety, as well as its ability to predict the risk of occurrence of angina, recurrent myocardial infarction and death after infarction (28–30). Early exercise testing contributed to the developing concept of risk stratification and the recognition of the need for further intervention. As outpatient rehabilitation programs have come into being, the graded exercise test, even when performed before discharge, has become a prerequisite first step.

Originally, exercise tests were performed to a level that approximated the degree of physical activity achieved during the latter days of hospitalization and were stopped on the basis of fixed end points, usually by heart rate or MET level (27). Even early studies showed that selected patients can be tested safely to symptom- or sign-limited end points (28,31). Currently, a heart rate of 130 beats/min or 5 METs is used for patients >40 years old, and 140 beats/min or 7 METs is used for patients <40 years old. A perceived exertion level (32) of 7 of 10 (new scale) or 15 of 17 (old scale) can also be used to end the test.

Evolution of risk stratification. Three factors virtually determine the prognosis of any patient after myocardial infarction: the amount of residual myocardium at risk, the extent of left ventricular dysfunction and the arrhythmic potential of the cardiac substrate. Predischarge risk stratification is intended to recognize persons at risk for death or reinfarction and those at low risk who need only conventional therapy to achieve a good prognosis (33).

During the 1980s, therapies for particular subsets of patients improved the survival rate after acute myocardial infarction (34). Predischarge exercise ECG testing may help identify those patients who might experience ischemically mediated events, such as subsequent infarction, and who are candidates for more aggressive interventions such as surgical revascularization (35). Figure 1 elaborates a simple scheme for risk stratification after myocardial infarction.

Topol et al. (36) established that submitting patients who are recovering from an acute infarction to exercise testing actually may expedite and optimize their discharge from the hospital. Early submaximal exercise testing is useful in evaluating patients with unstable angina for the presence of multivessel coronary artery disease after their condition has stabilized (37).

Predischarge low level exercise testing predicted subsequent events better than a submaximal test performed after myocardial infarction at 6 weeks. Almost 20% of patients tested early were unable to undergo testing 6 weeks afterward because of recurrent ischemia, infarction or death (38). Krone and colleagues (39) confirm that just performing a predischarge study is associated with a 10% lower mortality rate and a lower incidence of subsequent coronary events, but they imply that low level exercise testing is most useful in patients who exhibit other clinical markers of higher risk.

A trend toward earlier higher level testing is somewhat at odds with our understanding of the pathophysiology of myocardial infarction. The duration of the healing phase is about 6 weeks. Traditionally, we have assumed that a heart subjected to a major increase in rate or blood pressure during this period will experience deleterious effects. The hypothetical hazards of exertion in patients with myocardial infarction are cardiac rupture, aneurysm formation, extension of infarction, congestive heart failure and serious arrhythmias (22). In practice, these problems are rarely reported in patients who perform moderately intense exercise 1 or 2 weeks after infarction. However, for purposes of risk stratification, the point is that abnormal responses at higher work loads are not as predictive as those at lower work loads (40).

The efficacy of clinical judgment. Clinical judgment can also identify high risk patients (41), and ST segment shifts are not as predictive of high risk as an abnormal systolic blood pressure response or poor exercise capacity (40). When Froelicher and his colleagues (40) subgrouped the studies by time of testing (before discharge or after discharge), a high proportion of test results before discharge were accurate predictors of a poor outcome. Risk predictors from exercise testing best identify the patients who die early after myocardial infarction before later testing can be done. This finding coincides with the observation that one third of the 1st-year mortality occurs within the 1st 6 weeks after the acute infarction (35). The process of risk stratification has become an integral part of the management of patients during and after an acute myocardial event regardless of whether rehabilitation is planned (33).

Applying the findings of risk stratification. The results of risk stratification provide signposts for patient management throughout the rehabilitative process (Table 1). For example, a patient with poor ventricular function, an abnormal signal-averaged ECG and low exercise capacity preferably needs cardiac monitoring and exercise supervision in a hospital- or facility-based program. The patient is not a candidate, at least initially, for community-based group or unsupervised, unmonitored home rehabilitation. In contrast, a patient with an uncomplicated complete surgical revascularization can begin progressive activity in the home, undergo symptom-limited exercise testing when recovered surgically and continue exercising in a home- or community-based program. This patient may need some supervised training to ensure the appropriate understanding of the exercise prescription and for coronary risk factor education and modification. Levels of low, intermediate or high risk are also useful for program planning, especially for staffing and resource allocation (20) or for reimbursement of program services, such as ECG monitoring, according to current guidelines and standards (42).

Risk stratification guidelines. On behalf of the Health and Public Policy Committee of the American College of Physicians, Greenland and Chu (43) recommended that intermediate risk patients be defined as those who experienced shock or congestive heart failure during a recent (within 6 months) myocardial infarction, those who demonstrate <2 mm of ischemic ST segment depression or those who are unable to monitor their own activity or comply with the exercise prescription. They recommended for these patients a time-limited program rather than the typical full 8- to 12-week program.

They (43) defined high risk patients as those who have severe depression of left ventricular function (ejection fraction <30%); complex ventricular arrhythmias at rest; ventricular arrhythmia that increases during exercise; a decrease in systolic blood pressure ≥15 mm Hg with exercise; recent myocardial infarction (within 6 months) complicated by serious arrhythmias; survival of sudden cardiac arrest, or marked, exercise-induced ischemia indicated by angina ≥2 mm of ST depression, on the ECG. Patients with these clinical features are appropriate candidates for ECG telemetry monitoring during exercise.

Guidelines for risk stratification have been produced by other organizations as well. The American Association of Cardiovascular and Pulmonary Rehabilitation published its guidelines in 1991 (42), which indicate the extent of patient supervision and establish appropriate levels for service reimbursement. There are some major differences between the guidelines with regard to what markers discriminate, for example, between intermediate and high risk. Major differences between the two risk stratification schemes include <2-mm ST segment depression as an intermediate risk in one (American College of Physicians) versus >2-mm ST depression as an intermediate risk in the other; a changing pattern of angina is included in one scheme as intermediate but not specifically addressed in the other (American College of Physicians). The guidelines of the American Association of Cardiovascular and Pulmonary Rehabilitation also list combinations of ischemic markers thought to be associated with increased risk: functional capacity ≤5 METs with hypotensive blood pressure response or ≥1-mm ST segment depression; or ≥2-mm ST segment depression at a peak heart rate of ≤135 beats/min (42).

Regardless of how the various schemas are defined, the responses that reflect ischemia during exercise testing include not just ST segment (ECG) changes but also global exercise capacity and the presence or absence of angina. Ventricular function is best reflected by the ability to maintain an appropriate systolic blood pressure response and the accomplishment of adequate aggregate of work (41). Arrhythmic potential can be highly deceptive, but it is clearly a risk when sustained ventricular arrhythmia is present spontaneously or can be induced in the electrophysiology or exercise laboratory (44). Table 1 is derived, in part, from current guidelines, as well as from some of the newer means of identifying risk, and summarizes the characteristics of low, intermediate and high risk patients. Although low risk patients do not require ECG monitoring and close exercise supervision and intermediate risk patients may require only intermittent ECG monitoring, high risk patients are being seen more often in cardiac rehabilitation programs. For this reason alone, the future of institution-based phase II exercise rehabilitation programs seems secure.

Although there is no consensus as to the appropriate duration of monitoring needed for high risk patients, the preceding guidelines and the studies characterizing high risk patients suggest some means of appropriate allocation of the monitoring technology. Continuous monitoring is reasonable for high risk patients throughout their course of exercise therapy (43). After 8 to 12 weeks of such therapy with no adverse arrhythmia, patients who are otherwise in stable condition and are planning to continue exercise training can be monitored intermittently. Any destabilization of the underlying or related condition that may influence the arrhythmic potential, such as decompensated heart failure, requires stopping the exercise regimen until the problem is resolved and a stable rhythm is established.

Beyond risk stratification guidelines. Other factors, such as the presence of high frequency late potentials in the terminal portion of the QRS complex detected by signal averaging (45–47) or heart rate variability analyzed by power spectral analysis (48–51), have been identified as sensitive markers of risk for subsequent sudden cardiac death. These factors are relevant to the rehabilitative process because they appear to be time dependent and may be modified by exercise conditioning (52). This may explain the reduced incidence of sudden death in patients who participate in exercise rehabilitation, as reported by O'Connor et al. (53).

Figure 1 indicates how newer clinical technologies can be incorporated into risk stratification. Risk stratification needs to be an ongoing process. When patients were retested at 3 months after myocardial infarction, signs of ischemia were important predictors of outcome, whereas indexes of ventricular function were more predictive in the predischarge studies (54).

Integrating education into cardiac rehabilitation. Education about the cardiovascular disease process and information intended for reassurance and psychosocial support also are key elements in cardiac rehabilitation. Historically, patient education in the form of one on one counseling began during the course of routine hospitalization and was added to the structured exercise. Although hospitalization for an acute coronary event usually gets the attention of patients, often they are so overwhelmed by the pain, confusion, fear and anxiety of the experience that not much information is retained. We suggest straightforward responses to patients' questions in the early hours or days of the acute event followed by a more formal, structured educational process when the patient is further along in the physical and psychologic recovery. Repetition of key parts of the essential material is required to overcome emotional obstacles and is consistent with generally accepted learning theory. Studies suggest that such education can improve quality of life (55,56).

Growing importance of outpatient programs. With progressive shortening of the hospital stay, there is a greater need for structured outpatient rehabilitation programs in the home, hospital or community. The time spent in the hospital is not adequate to acquire the skills needed to monitor exercise activity or to cover the educational material adequately (57).

Outpatient programs began to appear in the mid-1960s. To some degree, they represented a direct extension of phase I. Several alternative models were available from the beginning. Zohman (58) advocated that exercise be performed in phase I under close medical monitoring and supervision, and this established a precedent that is followed today in many phase II formats in which continuous ECG monitoring and exercise supervision are both provided.

Alternatively, gymnasium-based programs with or without intermittent ECG monitoring also became popular (59–61). Data began to indicate the significant safety of outpatient exercise rehabilitation regardless of the model followed (62). The gymnasium- or community-based programs were identified as phase III and were thought to be ideal for persons who had graduated from phase II programs. However, by the late 1970s, patients with an uncomplicated course who were considered to be at low risk were being referred directly. The concept of risk stratification became more widely applied and was extended further in the mid-1980s by DeBusk et al. (63), who advocated home exercise programs, especially for those believed to be at low risk.

In what may be described as historical recapitulation, Fletcher and associates (64) proposed a stepped approach for outpatient exercise rehabilitation that takes into account patients' risk stratification status and their measured exercise ability. By applying the basic principles of frequency and duration and specifically basing intensity and progression on percent of maximal oxygen uptake, their protocols are defined so that each patient entering exercise training would gradually progress. The protocols consist of six phase II monitored levels designed to be completed within a minimum of six 1-h sessions and six phase II nonmonitored levels designed to be completed within 12 weeks. After safe completion of both components, patients can be referred to long-term maintenance programs.

At home rehabilitation as a primary mode of therapy. DeBusk (63) and associates (65–67) at Stanford have studied at home exercise quite extensively. Their earlier reports focused on the effects of home-based exercise training on peak oxygen consumption in healthy, sedentary, middle-aged men and, later, women. One study showed that self-monitored, home-based exercise training of moderate intensity significantly increased functional capacity in healthy, sedentary, middle-aged men and women (67). Moderate intensity training was performed five times a week in 50-min sessions. Subjects trained at 65% to 75% of maximal predicted heart rate, and after 6 months oxygen uptake increased by 15% in men and by about 10% in women. Such training provided a reasonable alternative to group-based exercise. The same group described the use of microprocessors to track home-based exercise training and found it to be practical (65).

They also compared medically directed at home rehabilitation with group rehabilitation beginning 3 weeks after uncomplicated acute myocardial infarction (63,66). Between 3 and 26 weeks after infarction, adherence to individually prescribed exercise was equally high (about 70%), the increase in functional capacity was similar (1.8 ± 1.0 METs) and nonfatal reinfarction and dropout rates were equally low (both ≤3%) in the subjects randomized to home or to group training. No training-related complications occurred in either group. DeBusk et al. (63) attribute the low rate of reinfarction and death (5% and 1%, respectively) in the study group to increased surveillance: a stepwise process of clinical evaluation, exercise testing at 3 weeks and frequent telephone contact of patients during the training period.

Realities of the Present

Changing demographics and the impact of aging. Both the absolute and relative proportions of the population who are older are increasing (68). This phenomenon is related to the current birth rate and to the decline in age-specific mortality. Thus, we can expect an increase in the absolute number of patients who have coronary disease (69), and these demographic changes will inevitably have a huge impact on health care utilization and expenditures (70).

The decline in cardiovascular deaths correlates with an increasing awareness and motivation to alter coronary disease risk factors. Improved treatments and risk factor modification through life-style change can reduce cardiovascular mortality (71,72). Because of the demographics of the increasing population, however, we must not misinterpret the decline in cardiovascular deaths to imply a lower future prevalence of disease, at least not in the next decade or two (69). If anything, we should expect the prevalence of coronary heart disease to increase about 30% by the year 2015, even with 20% to 25% decreases in case fatality and incidence rates (69).

Urberg and associates (73) documented rather striking changes in the demographic factors and the incidence of comorbid conditions among patients admitted for acute myocardial infarction. They found that men constituted 75% of the admissions to an urban hospital in 1980 and only 43% of the admissions in 1988. The percentage of diabetic patients increased from 27% in 1980 to 44% in 1988, and the diabetic patients were older on average than the nondiabetic patients. The findings corroborate our clinical experience that survivors of myocardial infarction today are older and sicker, and that this may be a future trend.

The demographic characteristics of those patients undergoing surgical coronary revascularization are changing as well (74). The patients who undergo coronary bypass surgery are characteristically older, more commonly female, advanced in age and likely to have three-vessel disease or left ventricular dysfunction. At the Cleveland Clinic the percentage of patients who undergo bypass surgery who are >70 years old has risen from 0.2% in the period 1967 to 1970 to >30% in 1989. More than 75% of procedures are now done for three-vessel disease, whereas 13% were performed between 1967 and 1970. Nearly 60% show some evidence of left ventricular dysfunction, whereas only 41% previously did (74).

Percutaneous transluminal coronary angioplasty is substantially changing the patient group that undergoes coronary bypass surgery. Patients who undergo coronary angioplasty are considerably younger (55 years vs. 68.5 years with 38% ≥70 years old), and most have only one- or two-vessel disease. The left ventricular ejection fraction in patients who undergo coronary bypass averages 38%; the fraction for those undergoing coronary angioplasty is 55% (75). Patients who undergo surgery today are older, have more complex disease and have intrinsically poorer pump function.

Thompson (76) has observed that the increase in the number and proportion of elderly persons will create constraints and pressures on our resources and services, and this will probably be reflected in our actions and attitudes about aging and the elderly. He observes further that the role of the aging person is evolving from our stereotype of the retired or grandparent role to a more active and participative one. The changing demographic profile compels us to anticipate newer approaches to health care for an older constituency. Although the primary concern is the development and administration of a system of services for the chronically ill, these health services must be coordinated to meet a wide range of needs (76).

Few data exist concerning the efficacy of cardiac rehabilitation for the elderly patient. The need for such programs has been advocated to slow the age-related decline in cardiovascular function (77) and to lessen the functional impact of age-related changes superimposed on disease-induced cardiovascular disability (78). Bruce et al. (79) have shown that regular activity, such as walking, leading to conditioning will also lower relative aerobic costs of everyday activities and that physical training can lower functional aerobic age in men with coronary heart disease to that produced by successful coronary revascularization. Ades and Grunvald (80) have shown in a nonrandomized study that the condition of elderly cardiac patients beginning at relatively lower level of fitness improved to the same degree as in younger patients. Gori et al. (81) found that poor compliance among elderly patients is most often related to medical problems and lack of motivation. Their participation in such programs is all the more important, however, because they are less capable physically, more dependent on others and have a smaller reserve than do younger patients.

Rehabilitation end points. With the establishment of successful earlier ambulation after myocardial infarction, the belief emerged that exercise would improve prognosis. Exercise is the fundamental element of cardiac rehabilitation programs, with the major focus on improving functional capacity and the contingent achievement of other important secondary goals. Major end points of rehabilitation outcome therefore include functional capacity, changes in psychosocial function, health education after acute ischemic event, morbidity and mortality, ventricular function, cardiac perfusion or collateral circulation and secondary risk factor modification (82).

Traditional measures of outcome—death, recurrent events, exercise improvement. Meta-analyses that reviewed randomized, prospective studies of cardiac rehabilitation versus usual care have confirmed its efficacy for the reduction of death after heart attack (53,83). Oldridge et al. (83) found that integrated programs of rehabilitation after myocardial infarction reduced mortality by 20% to 25%. Furthermore, the effects on mortality were influenced markedly by continuing the program beyond the usual 8 to 12 weeks. A significant impact on subsequent nonfatal myocardial infarction was not observed. In a meta-analysis of randomized trial of rehabilitation with exercise after myocardial infarction, O'Connor et al. (53) found reductions in cardiovascular mortality to be consistent with Oldridge's findings (83) and also found a 37% reduction in the incidence of sudden cardiac death during the 1st year after the acute cardiac event. We feel this reduction in the rate of sudden death is mostly related to the presence of skilled supervision and the early appreciation of clinical destabilization during the rehabilitation sessions, but the possibility that intrinsic changes may occur in the cardiac substrate or catecholamine-mediated responses to exercise clearly exists (50,52).

Despite Oldridge's findings (83), some data show that a comprehensive cardiac rehabilitation program can reduce the incidence of subsequent infarction. This was demonstrated in a study of a nonselected intervention in patients who survived acute myocardial infarction and who were randomly assigned to a rehabilitation program that included follow-up study at a special postmyocardial infarction clinic, exercise training, the provision of information on smoking cessation and diet and psychologic support to patients and their families. During the 5-year follow-up period, cardiac mortality did not differ between the groups, but the recurrence rate of nonfatal myocardial infarction (17.3% vs. 33.3%) and the rate of total cardiac events were lower in the intervention group (39.5% vs. 53.2%). This reduction may reflect an alteration of risk factors because there were fewer smokers and uncontrolled hypertensive patients in the intervention group. The program was particularly effective in those patients <55 years old who had significantly fewer cardiac events and who returned to work more often than members of the reference group (84). Again, the issue here may be related to the increased supervision inherent in a rehabilitation program and the ability to detect early destabilization.

Several studies (82) have documented improvement in exercise capacity with training by an average of 15% to 25%. Others studies have suggested, however, that patients will self-condition to adequate levels without formal exercise training (85), but that the rapidity of conditioning may be improved considerably. Investigators suggest that phase I rehabilitation in uncomplicated, low risk patients eliminates the need for phase II (86). Although the 15% to 25% improvement in patients who have normal exercise capacity has little practical impact, patients who have the poorest functional capacity are likely to derive the largest benefit from exercise training (87). This has significant implications for the design of cardiac rehabilitation programs (57,88).

Rehabilitation after surgical revascularization. Rehabilitation after coronary bypass surgery has been reviewed (89), but a brief mention is needed here. A number of studies have indicated the efficacy and long lasting results of rehabilitation. Weiner and others (90) reported in 1981 that sustained, measurable improvements in functional capacity occurred in patients who participated in exercise rehabilitation for 36 to 48 months. Oldridge et al. (91) have demonstrated a significant functional difference that persists in those who participate in exercise rehabilitation for extended periods. Froelicher and associates (92) showed increased oxygen uptake and decreased resting and submaximal heart rates after conditioning regardless of whether revascularization appeared complete or incomplete. This finding has implications regarding the efficacy of rehabilitation for incompletely revascularized patients regardless of the technique employed.

Rehabilitation after coronary angioplasty. Functional capacity has been improved with cardiac rehabilitation after coronary angioplasty, but this improvement may represent simple conditioning after relief of ischemic symptoms (93). Is exercise rehabilitation superfluous for those undergoing successful angioplasty? Ben-Ari and colleagues (93a) reported significant differences in work capacity and favorable changes in low and high density lipoproteins in those participating <6 months in a comprehensive rehabilitation program. Participation had no influence on the rate of restenosis (30% vs. 32%), however, or on the incidence of subsequent coronary bypass (5% vs. 4.4%) and myocardial infarction

(1.6% vs. 1.4%). Despite these findings, Hotta (94) sanctioned the use of rehabilitation after angioplasty in the Health Technology Assessment Report published in 1991. Contributing factors for his recommendation included the observation that the rate of return to work after angioplasty was disappointingly low, although the patients were physically capable. (The low rate may be related to the persistence of the "sick role.") In addition, he recognized that patients undergoing angioplasty may have previously damaged the myocardium or could not be completely revascularized. The indications for rehabilitation and stratification of risk apply regardless of the intervention. High risk patients will potentially benefit most, low risk patients the least and "patients with intermediate risk and function will likely benefit but may not require the full 12 weeks of participation" (94).

Implications for the Future

Surveillance after angioplasty versus after myocardial infarction. The mortality rate associated with acute myocardial infarction has improved greatly during the last 25 years, but the 1980s were especially significant because of the introduction of intravascular thrombolysis (95). In the majority of cases, mortality after thrombolysis has dropped to 3%, making a further reduction in mortality hard to obtain with newer treatment strategies. Will this have an impact on subsequent mortality and the likelihood that rehabilitation can reduce mortality even more?

Thrombolysis is producing more survivors of myocardial infarction who are left with variable amounts of healthy myocardium. As Muller and Topol have noted (95), the extension of these findings into the subset of patients >70 years old has significant implications. Patients who previously would have died are now going to be referred for rehabilitation as high risk candidates; those who would have been at high risk may now be at intermediate or low risk, and all will require aggressive modification of coronary disease risk factors to attenuate or reverse the progression of their coronary artery disease.

Patients who do not have recanalization after thrombolytic therapy have a poor clinical outcome (96). Interventions are performed increasingly to restore patency of large infarct-related vessels. Moreover, persistent ischemia in areas identified as potentially significant after myocardial infarction is likely to necessitate interventional or surgical revascularization. On this basis, fewer patients in rehabilitation are apt to experience improved mortality on the basis of less myocardium at ischemic risk. Angioplasty is associated with a high incidence of failure (97), however, and, if anything, phase II rehabilitation provides the kind of close supervision in which such failures can be detected early.

Although low level exercise thallium testing is useful in identifying the high risk patient after acute myocardial infarction, nearly half of the events after discharge are not predicted by low level exercise thallium testing before discharge in patients who receive thrombolytic therapy for acute myocardial infarction (98).

The detection of restenosis after successful coronary angioplasty can be improved with the use of a logistic model that combines procedural and follow-up variables (99). Using logistic discriminant analysis, Renkin and colleagues (99) developed a model for the prediction of restenosis. Recurrence of angina and exercise ST segment depression, both eminently observable phenomena with ECG monitoring and medical surveillance in the rehabilitation setting, were significant indicators for the recurrence of stenosis (99).

Secondary risk modification: vein graft atherosclerosis and restenosis after angioplasty. Interventional therapies for coronary artery disease are not curative but are temporary measures (100–104). The proportion of patients returning for a second and even a third coronary bypass operation continues to increase (105).

The traditional approach to secondary prevention of coronary artery disease is based on one to one professional counseling to help patients modify risk factors that promote progression of the disorder (106). A collective recognition of the need for prevention is occurring at a time when impending economic scarcity impels us to anticipate the enormous financial burden of providing such counseling and supervision to the huge group of people who require guidance to alter their life-style in a serious and meaningful way (107).

Recognition of the risk factors for coronary artery disease dates to the Framingham Study (108,109) in the 1960s. The effectiveness of cholesterol lowering for primary prevention of coronary heart disease has been suggested (103,107,110,111). Secondary prevention of atherosclerosis involves amelioration of the same risk factors (but after an acute event such as a heart attack or bypass surgery).

Aggressive treatment of hypercholesterolemia can slow and probably even reverse the progression of atherosclerotic lesions (111–113). Recent data suggest that life-style intervention alone, including exercise, diet and psychologic adaptation without cholesterol-lowering drugs, can arrest or reverse coronary atherosclerosis (114). Most important, such approaches can be targeted successfully toward patients who already have demonstrated major manifestations of the disease (115).

Whether cardiac rehabilitation can reduce coronary risk factors remains controversial (82). Although we believe that Kallio et al. (116) have demonstrated the efficacy of comprehensive rehabilitation for the postmyocardial infarction patient, Hedback et al. (117) have shown its efficacy for the reduction of multiple risks after coronary bypass surgery, and Ornish et al. (114) have shown its potential for patients who have obstructive atherosclerotic disease.

Expanded indications: arrhythmia, valve replacement and heart failure. The incidence of congestive heart failure is about 500,000 cases/year in the U.S., and the prevalence is about 2.5 million (118). With improved therapy such as angiotensin-converting enzyme inhibitors, home dobutamine therapy and others, we can expect that deaths from cardiac failure will continue to decrease and that more patients afflicted with this problem will enroll in group programs and be appropriate candidates for home exercise therapy (119). Although the number of patients who receive a cardiac transplant is small (≈2,500/year), because of the severe level of deconditioning by the time of the transplant procedure, virtually all these patients are rehabilitation candidates. The newer investigational procedure of myocardial myoplasty, still in its infancy, requires rehabilitative therapy for the training of the transpositioned latissimus dorsi muscle. Patients who are candidates for this procedure are similar to those who are transplant candidates and require significant reconditioning.

Implantable cardioverter-defibrillators that manage lethal arrhythmias have been successfully applied, particularly since the publication (120) of findings that drugs prescribed to suppress lethal or potentially lethal arrhythmias may cause more deaths than they prevent. These defibrillators, limited initially to patients with a history of sudden death, now are being placed increasingly in patients with susceptible cardiac substrate and ventricular dysfunction (121) in whom sustained ventricular tachycardia can be induced in the electrophysiology laboratory (122). More than 300,000 people/year sustain sudden cardiac death; a significant number of survivors will receive one of these implantable devices. These patients benefit from exercise (88) and have extraordinary needs for psychosocial support that can be met in the group environment of the phase II rehabilitation program (123).

On the one hand, the incidence of rheumatic heart disease is declining; on the other, the number of mitral valve repair procedures for myxomatous valve degeneration is increasing and aortic valve stenosis is also on the increase as an age-correlated problem (124). Although valvular heart disease affects far fewer patients than the number who undergo coronary bypass surgery, combined coronary bypass and valve procedures are becoming increasingly common (125).

Although the majority of patients who enroll in cardiac rehabilitation have coronary heart disease, as the emphasis shifts toward higher risk patients in monitored programs, patients with heart failure, a heart transplant, cardiomyoplasty, serious arrhythmias and an implanted device will constitute a larger minority of the participants (88).

Quality of life, a modern end point. Quality of life has become an increasingly prominent issue in cardiology and cardiovascular surgery during the last decade (126). Although interest has been focused on the high cost of therapy (coronary artery bypass surgery and interventional vs. medical management) (127), every therapy, regardless of its expense, now is regarded in the same way. Cardiac rehabilitation is no exception, and, as measures of quality become better understood and more standardized, it will be more closely scrutinized (128).

Our experience is that cardiac rehabilitation makes a significant difference in perceived quality of life. Many participants unquestionably enjoy and value their rehabilitation program, but does it make a measurable difference? Possibly not, according to Oldridge et al. (129) in a study in which disease-specific and generic health-related quality of life measures, including exercise tolerance and return to work after acute myocardial infarction, were examined in low risk patients who underwent brief rehabilitation. In virtually all cases, no differences were observed between those patients who participated in rehabilitation and those who received usual care (129).

Wenger (130) notes that the goal of therapy in patients with severe symptomatic heart failure is to lessen symptoms and maintain functional abilities and comfort and that hemodynamic features of heart failure (such as ejection fraction) are generally not well correlated with quality of life attributes. Low risk patients will probably recover normal performance of routine activities of daily living regardless of whether they participate in an exercise rehabilitation program. Rehabilitation is less likely to affect their perception of quality of life. For a person who is severely limited, however, even modest improvement will probably have a noticeable impact on functional capacity (131). It is ironic that patients with severely reduced exercise tolerance were formerly excluded from exercise rehabilitation on the assumption that they would derive little tangible benefit, defined as large, incremental measures in exercise function.

Oldridge and Rogowski (132) also recently looked at the efficacy of ward ambulation versus exercise in specialized centers for patients in phase I rehabilitation. Self-efficacy variables were measured at various intervals after the event up to 28 days after discharge. For the majority of self-efficacy variables, both approaches were equally effective. As discussed earlier in this chapter, historically, and for many institutions today, ward ambulation is the exercise mode of choice for inpatient care.

Economic evaluation of cardiac rehabilitation services. The study of Oldridge and Rogowski (132) raises the question of cost-effectiveness of rehabilitation. The financial impact of cardiac rehabilitation services was infrequently studied (133) until recently. As Dennis (134) has pointed out, cost effectiveness and cost-benefit considerations seem especially important in cardiac rehabilitation where little short-term impact but important potential long-term benefit on mortality, disability and psychologic well-being are expected.

Coors Industries (135) estimated recently that they save $6 for every $1 spent on their comprehensive wellness program, which includes mandatory cardiac rehabilitation for those employees who experience an acute coronary event. Picard and associates (136) examined the impact of rehabilitation on earned income and medical care costs and found that those persons who receive rehabilitation have higher earned incomes in the 6 months after an acute coronary event and generate $500 less in medical care costs. Ades et al. (137) found substantial differences in per capita hospitalization charges for those participating in rehabilitation versus nonparticipants and dropouts. This was a consequence of a lower incidence of hospitalization and lower charges per hospitalization. However, the study was not randomized and did not include the expense of rehabilitation as part of the economic analysis, and it did not include savings related to reduced physician services. Prospective, randomized trials are much needed to clarify this important issue.

Approximately 1 million people in the U.S. survive an acute myocardial infarction annually (115): approximately 10% to 15% of these patients subsequently are followed up in supervised outpatient cardiac rehabilitation programs (138). Assuming that supervised rehabilitation costs about $1,800 per patient, the annual cost of supervised cardiac rehabilitation is approximately $200 million. To make informed and appropriate decisions about the allocation of limited resources to various cardiovascular care services, comparative economic evaluation must be performed (139–141).

Cost-effectiveness and cost-benefit and cost-utility analyses. Economic evaluation may be defined as the comparative analysis of alternative courses of action in terms of both costs and consequences (141). "Costs" usually refers to the direct costs borne by health care providers and by the patient, whereas "consequences" include effects of the intervention, such as changes to the physical, social and emotional functioning of patients (142). Economic evaluations are classified according to the way in which consequences are measured in the analysis (140,141). In cost-benefit analysis, consequences are measured in terms of dollars; in cost-effectiveness analysis, consequences are measured in terms of natural units, such as life-days or life-years gained; and in cost-utility analysis, consequences are measured in quality-adjusted life-years (QALYs), which can be estimated by using the time trade-off technique (143).

Oldridge and co-investigators (129) included economic evaluation in the design of a randomized clinical trial of 8 weeks of comprehensive cardiac rehabilitation initiated after acute myocardial infarction. Patients with mild to moderate in-hospital anxiety or depression after acute myocardial infarction were randomly assigned to either rehabilitation or usual care. Outcomes, including health-related quality of life measured by time trade-off scores, were determined before and after the 8-week comprehensive cardiac rehabilitation intervention and again 4, 8 and 12 months later. By the end of the trial, cardiac rehabilitation patients had gained 19 quality-adjusted life-days (0.052 QALYs) per patient over usual care patients and made fewer other rehabilitation visits during the follow-up period of the trial (142).

The investigators then performed cost-utility and cost-effectiveness analysis during the 1-year study using life-years gained estimates from previously published meta-analyses of cardiac rehabilitation (53,83). The best estimate of net-direct 12-month costs (1991 U.S. dollars) for patients receiving cardiac rehabilitation after acute myocardial infarction was $480/patient with a cost-utility per quality-adjusted life-year gained of $9,200 over the year of follow-up. Using the reduced 3-year mortality from the meta-analyses of cardiac rehabilitation (53,83) and quality of life data from the present trial, the cost-effectiveness of cardiac rehabilitation after acute myocardial infarction was $21,800 per life-year gained, with an estimated cost-utility ratio of $6,800 per quality-adjusted life-year gained, establishing it as a more efficient use of resources than most treatments for coronary artery disease for which we have cost-utility estimates.

A brief office visit for smoking cessation (144), a daily aspirin for reducing the incidence of myocardial infarction (145), and beta-adrenergic antagonist therapy in a 55-year old man (146) are considerably more cost-effective than is cardiac rehabilitation. At $21,800 per life-year gained, the cost-effectiveness of cardiac rehabilitation is similar to that of propranolol for hypertension (blood pressure >94 mm/Hg) (147) and lovastatin (40 mg/day) for hypercholesterolemia (cholesterol >272 mg/dl) (148), but considerably more cost-effective than captopril for diastolic hypertension (blood pressure >94 mm Hg) (147) or lovastatin (80 mg/day) for hypercholesterolemia (cholesterol >272 mg/dl) (148).

The cost-utility estimate of $9,200 per quality-adjusted life-year was considerably lower than that for single-vessel bypass surgery or for treatment of diastolic hypertension (blood pressure >94 mm Hg) in a 40-year old man and was similar to the estimate for bypass surgery in patients with left main vessel disease (149). These economic data provide some important preliminary evidence that cardiac rehabilitation after acute myocardial infarction is an efficient use of health care resources and can be economically justified.

Conclusions. Cardiac rehabilitation has evolved as a therapy from the tentative empiricism of clinicians who prescribed progressively earlier ambulation in their patients after acute myocardial infarction. Its value in reducing morbidity and mortality remained in doubt for years, although it became accepted increasingly for the subjective improvement reported by patients. Ironically, its impact on traditional end points became moot in recent years with the advent of therapies that vastly decrease morbidity and mortality. Cardiac rehabilitation provides the ideal environment for supervising patients closely and for detecting early any destabilization after an interventional procedure. Patients who were formerly excluded from exercise training, such as those with significant left ventricular dysfunction, derive the greatest relative benefit from such training. Risk stratification provides a rational mechanism for determining appropriate need for cardiac monitoring and for professional supervision during exercise. The programs have become increasingly important as a means to modify coronary risk factors through exercise and education promoting behavioral change. Recent studies suggest that cardiac rehabilitation is economically sound.

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