REVIEW ARTICLE

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Cardiac Rehabilitation — Challenges, Advances, and the Road Ahead

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Each year in the United States, more than 1 million persons enter the turbulent waters of recovery after a cardiovascular event, such as myocardial infarction, percutaneous coronary intervention (PCI), coronary-artery bypass grafting (CABG), heart-valve surgery, or heart transplantation.[1] Surprisingly, only approximately 25% of patients who have had a cardiovascular event participate in cardiac rehabilitation,[2,3] despite its multiple proven benefits.[4]

Cardiac rehabilitation, which is also referred to as cardiovascular rehabilitation, is a multidisciplinary, systematic, yet personalized approach to providing evidence-based secondary prevention therapies for persons with cardiovascular disease. The roots of cardiac rehabilitation go back to innovative investigators who pushed past the status quo of their time and established a new paradigm for patients with cardiovascular disease. Further innovation is needed today to increase the reach of cardiac rehabilitation to all eligible patients with cardiovascular disease and to bridge the participation gap in cardiac rehabilitation programs, one of the largest gaps in the quality of care in cardiovascular medicine today.[2,5] This review addresses the current science and practice of cardiac rehabilitation, as well as the lessons learned from the past that will guide future directions in cardiac rehabilitation.

HISTORY OF CARDIAC REHABILITATION

> *Mater artium necessitas.* (Necessity is the mother of invention.)
>
> — William Horman, 1519[6]

Cardiac rehabilitation began in the mid-20th century in response to the need for effective rehabilitative care to address the high morbidity and mortality associated with myocardial infarction and recovery from it.[7] This development mirrored the earlier birth of physical therapy to meet the needs of patients affected by the poliomyelitis epidemic and soldiers wounded during World Wars I and II.[8] Patients recovering from myocardial infarction in the 1950s often had limited therapeutic options and were restricted from engaging in physical activity for 6 weeks or longer.[9,10]

As early as 1772, Heberden noted a possible role for exercise as a therapy for cardiovascular disease, reporting that a patient with angina who sawed wood 30 minutes daily for 6 months "was nearly cured."[11] Until the 1950s, however, physical activity was generally prohibited after myocardial infarction because of concerns about ventricular rupture and hypoxemia during myocardial healing.[12,13] In 1952, Levine and Lown reported that armchair exercise was both safe and beneficial for hospitalized patients recovering from myocardial infarction,[14] and Wenger subsequently introduced a progressive physical activity regimen initiated in the

intensive care setting.[15] Hellerstein and Ford extended cardiac rehabilitation to the outpatient setting,[16,17] a move that drew serious criticism because of safety concerns.[18] The safety of outpatient cardiac rehabilitation was reported by Kennedy and colleagues in a small but important study showing that an outpatient exercise training program for patients with stable angina improved oxygen consumption for a repetitive workload,[19] a finding that mirrored Heberden's observation some 200 years earlier.[11] In 1978, Haskell reported that in a study of 30 outpatient cardiac rehabilitation centers, severe cardiovascular complications were rare — about one fatal event per 100,000 patient-hours of cardiac rehabilitation exercise.[20]

As evidence emerged about secondary prevention for cardiovascular disease, cardiac rehabilitation centers evolved into centers of secondary prevention, providing nutrition therapy, psychological support, and management of risk factors for cardiovascular disease, in addition to exercise therapy.[21] When a chapter on cardiac rehabilitation first appeared in the second edition of Braunwald's textbook on heart disease in 1983, cardiac rehabilitation symbolically took an early step into mainstream cardiovascular medicine.[22] Important evidence of the benefits of cardiac rehabilitation has continued to emerge, including a meta-analysis by Oldridge et al. of 10 randomized, controlled trials that included 4347 patients and showed a 25% reduction in cardiovascular mortality among patients randomly assigned to cardiac rehabilitation.[23] Around this same time, the Centers for Medicare and Medicaid Services (CMS) began to provide coverage for outpatient cardiac rehabilitation services,[24] and guidelines were published in 1995.[25]

CARDIAC REHABILITATION PROGRAMS

The science and practice of cardiac rehabilitation have continued to grow over the past three decades. The current aim of cardiac rehabilitation is to help patients achieve the best possible cardiovascular health. Clinical practice guidelines from the American College of Cardiology (ACC) and the American Heart Association (AHA) recommend cardiac rehabilitation with supervised exercise training for patients with stable angina[26] or stable heart failure with a reduced ejection fraction[27] and for patients after myocardial infarction,[29,30] coronary-artery revascularization by means of either PCI or CABG,[31] or heart transplantation.[32] In addition, supervised exercise training is recommended for patients with symptomatic peripheral-artery disease[28] (Table 1). Worldwide, cardiac rehabilitation is also strongly recommended for these patient populations, particularly after myocardial infarction or revascularization procedures.[33,34,36]

Eligible patients enter the cardiac rehabilitation pathway when referred after a qualifying event or diagnosis, ideally beginning within 1 to 2 weeks after the event (Fig. 1). Prompt enrollment in cardiac rehabilitation appears to improve patient participation in the program; participation is 1% lower for every 1-day delay in enrollment.[37] Early enrollment also improves outcomes, with a 67% greater improvement in exercise capacity among patients enrolled in a program within 15 days after hospital discharge than among patients enrolled 30 or more days after discharge.[38-40]

On enrollment, patients undergo an evaluation that typically includes their history of cardiovascular disease, guideline-directed medical therapies, and coexisting conditions, as well as an assessment of their cardiovascular risk factors, exercise habits and capacity, dietary habits, body composition, psychological health, and quality of life. These evaluations are carried out by a trained, multidisciplinary cardiac rehabilitation team that generally consists of physicians, nurses, exercise physiologists, dietitians, social workers, and psychologists. This team designs an individualized treatment plan for each patient that is based on applicable evidence-based treatment strategies, as well as the patient's needs, goals, and preferences. The plan is reviewed and signed by a supervising physician and updated at least every 30 days to help patients advance in their rehabilitation efforts.[41,42]

The goals of cardiac rehabilitation (Table 2) are personalized, with the intent to help patients achieve cardiovascular health and guideline-directed targets for control of blood pressure, lipids, weight, blood glucose, and tobacco exposure; adhere to guideline-directed medical therapies; and reach targets for control of coexisting conditions, including psychological disorders, musculoskeletal limitations, and sleep apnea. Unstable conditions, such as unstable angina or severe hypertension, are stabilized by the health care team before pa-

Table 1. Clinical Practice Guideline Recommendations for Center-Based Cardiac Rehabilitation (CR) and Supervised Exercise Training.*

Clinical Practice Guideline	Recommendation	Class of Recommendation (Level of Evidence)†
Center-based CR		
ACC–AHA: coronary-artery revascularization[31]	Among patients who have undergone a revascularization procedure, a comprehensive home- or center-based CR program should be prescribed before hospital discharge or during the first outpatient visit, with the goal of reducing the risks of death and hospital readmission and improving quality of life	I (A)
ACC–AHA: STEMI[30]	Exercise-based CR and secondary prevention programs are recommended for all patients who have had STEMI	I (B)
ACC–AHA: unstable angina or NSTEMI[29]	All eligible patients with an acute coronary syndrome or NSTEMI should be referred to a comprehensive CR program, with the referral made either before hospital discharge or at the first outpatient visit	I (B)
ISHLT: heart transplantation[32]	CR with aerobic exercise training is recommended after heart transplantation; short-term benefits include improvement in exercise capacity and modification of CVD risk factors A total of 150 min of moderate-intensity exercise per week or 75 min of vigorous-intensity aerobic exercise per week is encouraged for long-term cardiovascular health	I (B)
ACC–AHA: chest pain[26]	For patients with obstructive coronary artery disease who have stable chest pain despite GDMT, exercise treadmill testing can be useful for selecting management strategies, including CR	IIa (B)
ACC–AHA: heart failure[27]	In patients with heart failure, a CR program can improve exercise tolerance, functional capacity, and health-related quality of life	IIa (B)
Supervised exercise training		
ACC–AHA: symptomatic peripheral-artery disease[28]	In patients with claudication, a supervised exercise program is recommended to reduce leg symptoms and improve functional status and quality of life	I (A)
ACC–AHA: heart failure[27]	For patients with heart failure, exercise training is recommended to improve functional status, exercise performance, and quality of life	I (A)

* The guidelines listed are U.S.-based guidelines for indications currently covered by the Centers for Medicare and Medicaid Services (CMS). Guidelines in other countries also recommend CR for patients with CVD.[33,34] Other indications covered by CMS but not included in the American College of Cardiology–American Heart Association (ACC–AHA) clinical practice guidelines are heart-valve replacement and heart-valve repair.[35] CVD denotes cardiovascular disease, GDMT guideline-directed medical therapy, ISHLT International Society for Heart and Lung Transplantation, NSTEMI non–ST-segment elevation myocardial infarction, and STEMI ST-segment elevation myocardial infarction.

† The level of recommendation ranges from class I to class III; class I indicates a strong recommendation, class IIa a moderate recommendation, IIb a weak recommendation, and class III no benefit. The designation A, B, or C refers to the level of evidence, with A indicating high-quality evidence (gained from more than one randomized, controlled trial), B moderate-quality evidence, and C either an expert consensus opinion or data from observational or registry studies.

tients start cardiac rehabilitation. At the beginning of each rehabilitation session, patients are assessed for signs or symptoms of unstable disease, and vital signs are monitored before, during, and after exercise.

Patients attend 36 cardiac rehabilitation sessions, each lasting 1 hour, over a period of 12 weeks, during which they participate in exercise training, nutrition counseling, and educational and psychological support sessions according to their individualized treatment plan and under the guidance of their cardiac rehabilitation team. The framework for a treatment plan and an example are shown in Figure 2 and in Figure S1 in the Supplementary Appendix (available with the full text of this article at NEJM.org).[42] Each patient's treatment plan includes personalized, guideline-directed exercise comprising cardiovascular, resistance, flexibility, and balance training. Patients recovering from cardiac surgery are guided through physical activities that are appropriate for protecting the healing sternum from injury.[43] Patients also receive nutritional counseling that focuses on fruits, vegetables, whole grains, nuts, beans, other protein sources with low saturated fat content such as fish, and calorie restriction

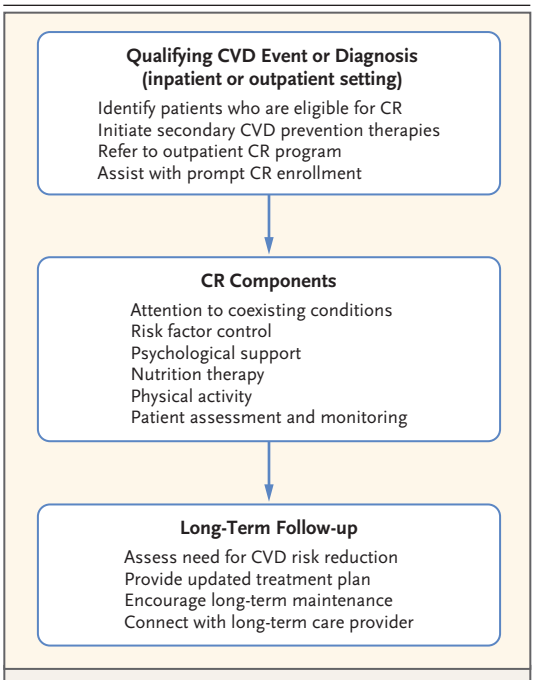

Figure 1. Cardiac Rehabilitation (CR) Pathway.

Important factors are listed for the three parts of the CR pathway, including steps to help patients initiate CR, components of an effective CR program, and steps to help patients maintain progress over time. CVD denotes cardiovascular disease.

as needed for weight control. The treatment plan includes strategies for psychological support, management of coexisting conditions, and assistance in adhering to guideline-directed medical therapy aimed at reducing risk factors for cardiovascular disease.[42,43] Electrocardiographic monitoring during cardiac rehabilitation is often used for patients with high-risk arrhythmias or other high-risk conditions but does not improve safety outcomes.[44]

At the completion of 12 weeks of cardiac rehabilitation, patients undergo a graduation assessment that focuses on progress made toward meeting their goals for exercise, nutrition, psychosocial factors, and other core factors, such as control of cardiovascular risk factors and adherence to guideline-directed medical therapies. The treatment plan is then updated to help patients continue to advance toward their rehabilitation goals after discharge from the program. A longer-term follow-up plan is also developed, to be carried out with the assistance of the patient's cardiologist or primary care provider.

The traditional cardiac rehabilitation program is based in a hospital outpatient area or an outpatient clinic. Home-based cardiac rehabilitation, delivered outside the traditional cardiac rehabilitation center, has been studied since the 1990s but was rarely used in the United States until the coronavirus disease 2019 (Covid-19) pandemic, when center-based cardiac rehabilitation programs out of necessity considered home-based cardiac rehabilitation options, which were temporarily covered by CMS during the public health emergency.[45] With the end of the Covid-19 public health emergency, the future of coverage for home-based cardiac rehabilitation is unclear.

RECENT CHALLENGES AND ADVANCES IN CARDIAC REHABILITATION

Despite the myriad changes and challenges in cardiovascular medicine today, advances in cardiac rehabilitation have helped it grow in relevance and recognition. These advances are reflected by the growth in scientific publications in the field over the past 20 years.[46] Studies have focused on several issues, some of which are highlighted below.

BENEFIT OF CARDIAC REHABILITATION TODAY

Given the risk factors and lifestyle habits of many patients with cardiovascular disease,[47,48] cardiac rehabilitation continues to be beneficial by systematically helping patients apply evidence-based secondary cardiovascular disease prevention therapies. Benefits from cardiac rehabilitation include improvements in functional capacity,[49] psychological health,[50] adherence to treatment,[51] control of risk factors for cardiovascular disease,[52] return to work,[53] and health-related quality of life,[4] with reductions in hospital readmission rates[4] and cardiovascular death rates.[4]

Although reductions in mortality have been reported previously in randomized trials,[23,54] a systematic review suggests little or no effect of cardiac rehabilitation on all-cause mortality.[4] This finding may be due to improvements over time in the usual care of patients or to quality issues in the trials themselves.[55] All-cause mortality benefits are clear in large observational studies[56] and show a dose–response association, with a 1 to 2% reduction in mortality for each cardiac rehabilitation session attended.[57,58] Although this relationship may be due, in part, to healthy participant bias, the cardiac rehabilitation session dose–response is consistent with the dose–

Table 2. Goals of CR and Examples of Actions to Help Meet Goals.*

CR Goal	Examples of Actions to Meet Goals
Optimize recovery after a cardiovascular event or procedure	Learn and effectively apply principles that promote the following goals: Physical healing and recovery (e.g., proper wound care if indicated, safe and gradual increase in physical activity) Emotional and psychological healing (e.g., understanding normal vs. abnormal feelings and symptoms after a cardiovascular event) Return to work and other meaningful activities
Optimize functional capacity	Safely and effectively apply an individualized exercise plan that includes the following components: Aerobic exercise training (gradually progressing to 5–6 days/wk, ≥30 min of vigorous activity) Resistance training (gradually progressing to 2–3 sets of 8–10 exercises of moderate-intensity resistance training, 2–3 days/wk, ≥15 min/day) Flexibility training Balance training
Optimize cardiovascular health	Adopt and maintain guideline-directed dietary and exercise recommendations focused on the following goals: Reduce risk of future cardiovascular events Maintain tobacco-free living Optimize control of modifiable cardiovascular risk factors (elevated lipids, blood pressure, blood glucose, tobacco use, obesity) Adhere to guideline-directed medical therapies that reduce risk of future cardiovascular events Identify any noncardiovascular coexisting conditions that may be barriers to cardiovascular and general health (e.g., obstructive sleep apnea, musculoskeletal disorders) and refer patient for treatment
Optimize psychological health	Identify and treat clinically significant psychological disorders (e.g., anxiety, depression)
Optimize quality of life	Establish or strengthen sources of social support (e.g., family, friends, church group) Identify and address adverse social determinants of health that may be barriers to one or more CR goals

* Listed are general goals and examples of related actions that are included in a patient's treatment plan for CR and tailored to the patient's specific conditions, needs, and preferences. The patient and the rehabilitation team work in partnership to carry out the goals.

response effects of individual components of a cardiac rehabilitation program, such as exercise training and statin therapy.[59,60] On the basis of a systematic review of randomized cardiac rehabilitation studies, the number needed to treat to prevent one myocardial infarction at 12 months is 75 and the number needed to prevent one hospital readmission is 12.[4] Observational data suggest that the number needed to treat to prevent one death is 34 at 1 year and 22 at 5 years after PCI.[61] The safety of contemporary cardiac rehabilitation was reaffirmed with the finding that one cardiac arrest was reported for every 1.3 million patient-hours of cardiac rehabilitation exercise.[44]

Cost–benefit studies are generally favorable with respect to cardiac rehabilitation.[4] One study reported a savings of $2,920 (Canadian dollars) per year in medical expenditures for persons with cardiovascular disease who completed a program of cardiac rehabilitation, as compared with those who were not referred to cardiac rehabilitation.[62] A systematic review showed that cardiac rehabilitation is cost-effective, with an incremental cost-effectiveness ratio ranging from $1,065 to $71,755 per quality-adjusted life-year gained and the most recent studies showing the most favorable results.[63]

BRIDGING THE PARTICIPATION GAP IN CARDIAC REHABILITATION

Despite the known benefits of cardiac rehabilitation, its impact on the cardiovascular health of the general population has been limited by low participation. However, this may be changing in the current era. A 2020 report indicated that participation in cardiac rehabilitation programs has increased in subgroups of patients, primarily those undergoing coronary-artery revascularization with CABG or PCI.[2] Among patients undergoing CABG, participation increased from 31% in 1997 to 55% in 2020. For patients who had a

myocardial infarction and were treated with PCI, participation in cardiac rehabilitation increased from 21 to 33%. Participation among patients in these groups, although improved, is still low. Unfortunately, participation dropped among patients with a myocardial infarction who did not undergo revascularization, from 11% in 1997 to 7% in 2020. Overall, only 24% of eligible patients participated in cardiac rehabilitation in 2020, one of the more striking and persistent gaps in cardiovascular care today.[5] Furthermore, only 24% of eligible patients who began cardiac rehabilitation did so within 21 days after the qualifying event, and only 27% completed a full course of cardiac rehabilitation.[2]

The participation gap affects all eligible patients, but disparities are most pronounced for women, older patients, racial or ethnic minority groups,[64] patients in lower socioeconomic groups, and those living in areas with limited numbers of cardiac rehabilitation programs.[2,65] Only 18.9% of women, 9.8% of patients older than 85 years of age, 13.6% of non-Hispanic Black patients, 13.2% of Hispanic patients, and 6.9% of dual Medicare- and Medicaid-eligible patients participate in cardiac rehabilitation.[2] Although 39% of eligible patients participate in cardiac rehabilitation in the West North Central Census Division, only 20% participate in other regions of the country, including the East South Central, West South Central, Middle Atlantic, and Pacific Census Divisions.[65] These patient groups face substantial barriers to cardiac rehabilitation referral and participation, barriers that appear to be eliminated with systematic referral strategies[66] and more tailored participation options.[64,67]

Our understanding of barriers to participation in cardiac rehabilitation programs has grown over the years, as has the discovery of effective solutions with varying degrees of anticipated effect and difficulty in implementation (Fig. 3).[67] The percentage of patients who participate in cardiac rehabilitation can be increased with the use of automatic referral systems and patient navigators.[68] These interventions have been shown to boost patient participation in cardiac rehabilitation from 30 to 74%.[66,68] However, implementation is challenging for many centers.[71] In addition, the capacity of existing cardiac rehabilitation programs in the United States is well below what is needed; estimated capacity is sufficient to accommodate only 37% of eligible patients.[72]

Financial and insurance constraints are potentially correctable barriers to cardiac rehabilitation. Patients with no cost-sharing, such as copayments or deductibles, for their cardiac rehabilitation sessions attend, on average, 6 more sessions than those with any cost-sharing — a difference that would theoretically translate into a reduction in mortality of 6 to 12%, assuming a reduction in mortality of 1 to 2% per session attended[73] and a reduction in hospital readmission rates and associated costs of approximately the same amount.[4] Incentives — both financial[69] and nonfinancial[68] — also appear to improve participation in cardiac rehabilitation programs. One study showed that moderate financial incentives resulted in a doubling of the program-completion rate among patients covered by Medicaid.[69]

Other strategies that have been implemented to improve participation in cardiac rehabilitation are clinical practice guidelines (Table 1) and performance measures,[3,7,74] including measures from the National Committee for Quality Assurance Healthcare Effectiveness Data and Information Set that address cardiac rehabilitation initiation, attendance, and completion.[75] In collaboration with the American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR), the Million Hearts Cardiac Rehabilitation Collaborative, a multidisciplinary group with members from academia, government agencies, clinical care, and industry, has produced both a road map of strategies and a Cardiac Rehabilitation Change Package to help increase participation in cardiac rehabilitation to at least 70% nationally.[70,76]

Certification programs that promote patient participation and high-quality cardiac rehabilitation have also been implemented. Examples include the Joint Commission's Comprehensive Cardiac Center Certification, which includes cardiac rehabilitation as one of its key components,[77] the AACVPR cardiac rehabilitation program and professional certifications, the European Association of Preventive Cardiology clinician certification in preventive cardiology, and the Cardiovascular Rehabilitation Foundations Certification program of the International Council of Cardiovascular Prevention and Rehabilitation, which shares resources with cardiac rehabilitation programs around the world.[78] Although the effect of these quality-improvement efforts is not yet known, evidence suggests that groups that adopt quality-

Components			Assessments and Plans at Program Entry		
Exercise	**Assessments**				
	Aerobic exercise capacity		6-Minute walk test: 357 m		
	Strength		1 Rep maximum leg press: 60 kg		
	Flexibility		Sit and reach: −5.08 cm		
	Balance		Single leg stance: 3 sec (right), 7 sec (left); tandem walk: 9 steps		
	Fall risk		Low		
	Symptoms		None		
	Plan				
			Aerobic exercise	Strength exercise	Flexibility
	Patient goals		Increase exercise capacity so I can walk up hills in my neighborhood each day without stopping	Increase my strength so I can shovel snow in the winter	Increase my flexibility so I can bend over to lift something off the floor
	Interventions	Mode	Walk on treadmill	Hand weight routine	Stretching routine
		Frequency	3 days/wk in center 2 days/wk in home	3 days/wk in center	3 days/wk in center 2 days/wk in home
		Duration	15 min/day	8–10 exercises 5–10 repetitions 1 set, 10–15 min/day	10 min/day
		Intensity	Moderate (rate of perceived exertion 10–11/20)	Moderate weight, fatigued after 10 repetitions	Stretch/hold to count of 5, increase to count of 10 over next month
		Progression	Increase by 1–5 min/day each wk to 40 min/day	Increase 1–5 lb/wk Increase sets to 2–3	Perform to point of tension, avoid pain
	Education		*Basics of Exercise Training* (video and booklet)	*Basics of Strength Training* (video and booklet)	*Basics of Flexibility Training* (video and booklet)
Nutrition	**Assessments**				
	Height/weight		165 cm/85 kg		
	Body composition		Fat: 24.5 kg (35%); lean: 43.4 kg (62%); bone tissue: 2.1 kg (3%)		
	Waist/hip circumference		86.4 cm/92.4 cm		
	Body-mass index		31.2		
	Dietary habits		Diet score: 52 (optimal >60)		
	Plan				
	Patient goals		Increase my intake of fruits and vegetables to 5 servings each day Decrease my waistline by 1 inch in the next 3 mo		
	Interventions		Meet with dietitian and develop dietary plan Track progress at home, report each week to my care team		
	Education		*Basics of Healthy Nutrition for the Heart* (video and booklet); *Basics of Healthy Weight* (video and booklet)		
Psychosocial Support	**Assessments**				
	Anxiety		Mild		
	Depression		Low		
	Quality of life (overall health)		Good (3/5)		
	Social determinants of health		Transportation problems		
	Plan				
	Patient goals		Reduce my feelings of anxiety about exercise Have a strong support group around me to help me		
	Interventions		Meet with social worker each week to discuss stress reduction Connect with my family more often for help with transportation		
	Education		*Basics of Stress Management* (video and booklet); *Basics of Mental Health after Heart Surgery* (video and booklet)		
Other Core Factors (cardiovascular risk factors and other factors that apply to the patient)	**Assessments**				
	Tobacco use		No tobacco exposure		
	Hypertension control		Hypertension: yes; 6-hr blood pressure average: 124/76 mm Hg		
	Lipid control		Dyslipidemia: yes; LDL cholesterol: 45 mg/dl; triglycerides: 87 mg/dl; non-HDL cholesterol: 75 mg/dl		
	Diabetes control		Diabetes: no		
	Guideline-directed medication therapy		Aspirin: 81 mg daily ACE/ARB: lisinopril, 20 mg daily (EF 45%) Beta-blocker: metoprolol succinate, 50 mg daily (EF 45%) Statin: rosuvastatin, 20 mg daily (baseline LDL cholesterol, 115 mg/dl) Nitroglycerin: SL tablets to use as needed for chest symptoms		
	Other coexisting conditions		Sleep apnea (on CPAP therapy); central obesity		
	Plan				
	Patient goals		Hypertension: weekly average blood pressure <130/80 mm Hg Dyslipidemia: LDL cholesterol <55 mg/dl Medications: take daily as directed Sleep apnea: use CPAP each night		
	Interventions		Hypertension: lifestyle and medication therapies prescribed Dyslipidemia: lifestyle and medication therapies prescribed Medications: use daily reminder system to take pills on time daily Sleep apnea: CPAP, follow-up with Sleep Medicine Center		
	Education		*Basics of Hypertension* (video and booklet); *Basics of Dyslipidemia* (video and booklet); *Basics of Taking Medication as Prescribed* (video and booklet); *Basics of Sleep Apnea Management*		

Figure 2 (facing page). Example of an Individualized Treatment Plan at CR Program Entry.

An example of an individualized treatment plan at the time of program entry is shown for a 63-year-old woman who has undergone CABG and is considered to have an intermediate risk level. The plan guides the CR team in carrying out the patient's CR program and is reviewed and updated at least every 30 days during the 12 weeks of the program to improve the patient's progress. The flexibility measurement on the sit-and-reach test is 0 cm if patients are able to reach and touch their toes, <0 cm if they cannot reach their toes, and >0 cm if they can reach beyond their toes. The body-mass index is the weight in kilograms divided by the square of the height in meters. To convert cholesterol values to millimoles per liter, multiply by 0.02586. To convert triglycerides to millimoles per liter, multiply by 0.01129. ACE denotes angiotensin-converting–enzyme inhibitor, ARB angiotensin-receptor blocker, CPAP continuous positive airway pressure, EF ejection fraction, HDL high-density lipoprotein, LDL low-density lipoprotein, and SL sublingual.

improvement strategies can significantly increase participation in cardiac rehabilitation.[68,79,80]

HOME-BASED CARDIAC REHABILITATION

Since DeBusk and colleagues showed the positive benefits of home-based cardiac rehabilitation in 1994,[81] home-based programs have been seen as a promising solution to bridge the gap in the delivery of cardiac rehabilitation, especially for underserved groups. Home-based cardiac rehabilitation uses the same clinical components and trained personnel as center-based cardiac rehabilitation, differing only in the location where the program occurs. Patients communicate with cardiac rehabilitation staff members through telephone, video, or other messaging options either when they are exercising (synchronous communication) or at a time when they are not exercising (asynchronous communication). So-called hybrid programs use a combination of center-based and home-based cardiac rehabilitation.[82]

In 2019, an AACVPR–ACC–AHA scientific statement summarizing evidence on home-based cardiac rehabilitation with either synchronous or asynchronous communication reported short-term benefits that were similar to those with center-based cardiac rehabilitation.[83] The statement concluded that home-based cardiac rehabilitation would be a reasonable alternative for persons who could not participate in center-based cardiac rehabilitation, with the caveat that longer-term outcomes and additional data are needed for women, racial and ethnic minority groups, and older persons.

Adherence to home-based cardiac rehabilitation appears to be higher than adherence to center-based cardiac rehabilitation, probably because of the greater convenience of a home-based program.[84] A recent observational study comparing home-based cardiac rehabilitation with center-based programs, which involved a diverse population in southern California, showed similar rates of attainment of secondary prevention targets and lower 12-month hospital readmission rates among groups of patients who participated in home-based programs.[85] A Veterans Administration observational study comparing participation in a home-based program with no participation in cardiac rehabilitation showed that mortality was 36% lower among patients who chose home-based cardiac rehabilitation than among those who chose not to participate in cardiac rehabilitation.[86] Initiation of cardiac rehabilitation also appears to be higher for home-based cardiac rehabilitation than for center-based programs (43% vs. 13%).[87] The cost effectiveness of home-based cardiac rehabilitation is favorable, but how it compares with the cost effectiveness of center-based cardiac rehabilitation is unclear.[88]

Several factors will determine whether home-based cardiac rehabilitation will help reduce the participation gap. These include evolving standards and regulations for home-based cardiac rehabilitation; evolving standards for the development, testing, and implementation of technological tools that may help improve the speed at which effective strategies for home-based cardiac rehabilitation can be used[89]; financially viable reimbursement strategies; and an alignment of cardiac rehabilitation delivery models with reimbursement strategies and regulatory groups so that home-based and center-based cardiac rehabilitation are seen as interchangeable.

FUTURE DIRECTIONS

"Necessity remains the mother of invention."

— Clayton M. Christensen, 2003[90]

The future of cardiac rehabilitation for eligible patients will include an array of tools and strate-

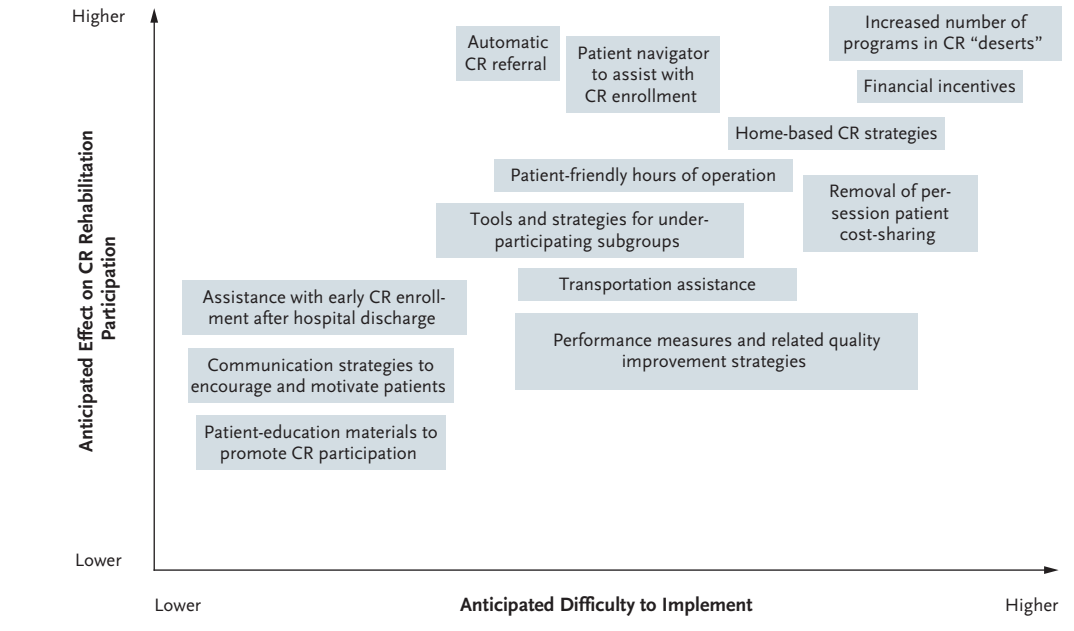

Figure 3. Potential Solutions for Bridging the Gap in CR Participation.

Shown are the potential solutions for overcoming barriers and improving participation in CR. The potential solutions are graphed according to their anticipated effect on CR participation and the anticipated difficulty in implementing them.[40,64,66-70]

gies to help deliver effective cardiac rehabilitation to increasingly diverse patient groups in various locations — from centers to homes to anywhere else they are throughout the day (at work, traveling, etc.). Advances in cardiac rehabilitation will also result from new intervention strategies and interactive tools, including wearable technologies, physiological monitors, and communication devices. These advances will help expand the effective options for interacting with and guiding patients in the short and longer term, with the use of a menu of evidence-based options tailored to each patient's characteristics, needs, and preferences.[89] Eligibility for cardiac rehabilitation will be expanded to address the needs of other patient groups, including patients with coexisting cardiovascular disease and cancer, patients with heart failure and a preserved ejection fraction, patients with atrial fibrillation, and those with congenital heart disease. Cardiac rehabilitation will progressively be delivered before, not only after, a procedure is performed in a patient with cardiovascular disease (i.e., "prehabilitation"). Certainly, the highest priority for future improvement of cardiac rehabilitation will be to deliver longer-term, high-quality cardiac rehabilitation services to all eligible patients. New models, strategies, and tools will be essential as cardiac rehabilitation professionals and policymakers seek to move from a state of status quo — cardiac rehabilitation with high value but low utilization — to a state of "new and improved" — cardiac rehabilitation with high value and high utilization.

CONCLUSIONS

Cardiac rehabilitation began through innovative efforts to help patients recover after a cardiovascular event. Despite its known benefits, currently only a minority of patients participate in cardiac rehabilitation. Clinicians, administrators, and policymakers share responsibility for implementing effective steps to engage patients, support high-quality cardiac rehabilitation, and open pathways that lead all eligible patients toward the best possible cardiovascular health.

Disclosure forms provided by the author are available with the full text of this article at NEJM.org.

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